OUR HOMES

SHIRLEY F. MURPHY.

Our Homes,

AND

HOW TO MAKE THEM HEALTHY.

Frontispiece to "Our Homes."]

TERRACE HOUSE, SHOWING FOUNDATIONS AND DRAINAGE.

A. Ventilating shaft for air inlet and access to drain.
B. Syphon traps.
CC. Drain enclosed in concrete.
D. Open pipe for bath waste.
E. Yard gully.
F. Soil pipe carried up above eaves, as ventilating shaft
G. Shaft for access to upper end of drain.
HH. Ventilating damp proof course.

OUR HOMES,

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HOW TO MAKE THEM HEALTHY.

BY

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CHAPTER XCII.

OUR HOMES,

AND

HOW TO MAKE THEM HEALTHY.

HEALTH IN THE HOME.

By Benjamin Ward Richardson, M.D., LL.D., F.R.S.

IN the dialogue between Socrates and Critobulus, which Xenophon invents, he makes Socrates declare that the ordination of the house is the name of a science, and that the science means the order and increase of the household. It is in the spirit thus expressed that the writers of this work enter on their task. They aim to make the ordination of the house the name of a science, — the science of domestic sanitation.

Domestic sanitation, in its scientific sense, must be subject to change, according to the places in which the details of it are studied and carried out. The climatic conditions of the place; the modes of life and the trainings of the persons who are to be housed; the occupations of the people; the physique of the people; and the number of persons who occupy a given space in a village, city, or town; all these influences have to be considered by him or by them who would supply good rules for the ordination of the house that is to be both commodious and healthy. We cannot in the present work charge ourselves with universal labour on these subjects. We must confine our efforts chiefly to the homes of our own countrymen, to the homes that are included in the hamlets, villages, towns, and cities of the British Islands. We have no occasion to regret this limitation of our labours. In endeavouring to improve the existing state of native domestic sanitation we have a task before us sufficient to test all our powers to the fullest degree.

Our country, developing in successive stages under what may be called successive civilisations, has been supplied with habitations that are as varied in construction as they are diversified by necessity. The first of these peculiarities need not be matter of regret, for it must be admitted that variety of construction may, within moderate limits, be conducive to artistic excellence and to that pleasure of mind which is necessary to relieve monotony, and thereby to minister to health. The second of these peculiarities is a real cause for regret, because when there is no uniformity of knowledge or of action in respect to what is necessary for the

maintenance of health, and when, in regard to this great common interest, views and practices and minor interests clash and confuse, then difficulties stand in the way which nothing can remove until the most careful instruction, appealing in a decisive and at the same time simple manner to the conviction of the people generally, is imparted to them.

I do not think I can fulfil the duty that now devolves on me better or more usefully than by indicating the principles, the objects, and the practice of domestic sanitation which form the necessities of a true sanitary code. My able colleagues will fill up the details, and to them I leave that important part of our undertaking. I must be content to step, as it were, a little before them, and, like a pioneer, survey and clear the ground.

Uniformity in domestic sanitation is the first requirement. In some of our great centres of life there have been introduced certain regulations which seem to inculcate uniformity of system on a few points, such as supply of water and removal of sewage from the dwelling. But in these particulars all is local, and localities divide in opinion to an extent that, in the most determinate degree, prevents steady progress. There is, in fact, no system at all, either of a legislative or domestic kind, by which a healthy condition of the household may be sustained. Practically every master of a house is a law unto himself.

For my part, I would not urge any decisive change from the rule of every man being a law unto himself in sanitary affairs as they affect the domestic life. It would be far better for every man and woman to know what is necessary for the sanitary welfare of those who are entrusted to their care, and for them, on their own responsibility, to carry out needed reforms on a few sound principles, than for any number of legislative acts to be forced, by the intervention of outside inquiry or infliction of outside pressure, on an unprepared, resisting, or doubting community. We shall therefore best effect what we have in view by indicating the principles of uniformity in sanitation, and by explaining what can reasonably be carried out by every man in his own place. If in the centres called home the foundations of the science of health are laid, the rest, on a larger scale, will necessarily follow, for the same rule that applies to the accumulation of wealth applies equally to the accumulation of health. "Take care of the pennies," says the Financier; "the pounds will take care of themselves." "Take care of the houses," says the Sanitarian; "the towns will take care of themselves."

While from the above remarks it will be inferred that individual action in relation to health is the foundation of sanitary reform, it must not be assumed that legislative action is to be ignored. It will be the task of some trained scholar in this work to present a clear and concise review of the position of legislation in these islands in relation to health. The description that will thus be supplied will divide naturally into two heads: the general and the local. The general legislation will be seen to refer to those measures which extend throughout the Commonwealth; the local will be seen to refer solely to the work of individual communities. It is possible that in the end there will be discovered to exist a third legislative direction, in which the two first are combined, to the obstruction, if not to the destruction, for all practical

good, the one of the other. The laws that are in this day in force have indeed an influence on individual domestic sanitation which, for good or for evil, is decisive in correcting free will. If in London the best sanitarian has plans of his own for building a house on what he conceives to be the truest sanitary principles, it is all but impossible for him to carry out his design without having it in some way crossed by the control which belongs to the Metropolitan Board of Works, or, by the legal restraints of property. Nay, if it should so happen that his knowledge were better than that of other persons, he might still be obliged to submit to the lesser knowledge. and be prevented making any progress even in an effort that, by the example it sets forth, could be made useful to all the community. I do not adduce this as matter of complaint. In all large communities packed closely together it is essential that certain general rules shall be laid down by some central authority that shall govern the whole on something like a uniform system, and it would probably be bad policy to allow genius, even of the highest order, to execute special plans that were out of the general scheme which belongs to the whole of the local system. I only adduce a matter of fact as a reason for the argument I would offer relative to general, local and individual practice in sanitation.

The principle we have to strive after is one that will tend to make general legislation uniform, local legislation in harmony with general, and individual action compatible with both. In a word, uniformity of sanitative action is the need for which we have to contend. For this purpose the home must be the source of our national health. As the great rivers spring from little sources which a child can leap over, so the rivers of health must spring from the hearths of the people. The man who is fully competent to vote for a sanitary legislator, local or general, is a man who in his own house is capable of judging whether the said house is in a healthy or in an unhealthy condition, and a man who is acquainted with the intention and object of the art of preserving and maintaining health. I mean by this that the man who will prove to be the best sanitarian is he who will apprehend with equal facility the reasons for the practice of sanitation as well as the practice itself.

THE WORK TO BE DONE.

The domestic sanitarian who would make himself fully conversant with sound reasons for the reforms which he is anxious to introduce into his household, must first of all learn that he has something to prevent. He has to prevent unnecessary disease, and thereby unnecessary mortality.

If the inquirer turn to investigate the scope of this work, he will do much to reassure himself. He will learn that though his own effort be small, and, as it may seem, in the midst of so much that is confusing, incalculable, it is worthy of his endeavour. He will find that even in this civilised country little more than a third of the value of life that is given to his species is realised, not to say enjoyed. The anatomical physicist will explain to him a law by which the relative lengths of life of man and of all the domestic animals may be fairly measured by the period in which the complete development of the skeleton is attained. A simple calculation will then tell the natural duration of the life of the animal. The

multiplication, by the number five, of the period of completed development will give the standard necessary. The maturity of man, calculated by the completed condition of the skeleton, is twenty-one years. Twenty-one years multiplied by five—one hundred and five years—is therefore the natural duration of the life of man on this estimate, and, with a certain natural limited range, may be accepted as the true and full duration. But when the actual value of life is taken it is found to present, in this country, an average of forty-two years, so that there are grand agencies at work which are reducing the national life to a very low value.

If the inquirer enter further into the matter, he will observe that the grand agencies leading to this reduced value of life must be in some way removable, because they are not always in action to reduce every form of life to the same level of duration. He will discover that the domestic animals which surround us, if we do not kill them outright by hard labour, privation, or exposure to the vicissitudes of seasons, are so much longer lived than we are, that they exist, practically, to their full term with as much exactitude as we exist to the first part of our second stage of existence. Or, to put the matter in another light, he will discover that if our lower domestic animals were to die in the same ratio that we die, their duration of life, as it is now known, would be reduced nearly to half what it is. The dog would have an average term of eight years, and other animals a similar reduced term of life.

Such observations as these will lead the sanitarian to find a uniform object in his labour. He will ask what is the reason why man, who holds all the knowledge and skill above the brute creation, should have so little control over his own destiny that he cannot control it in respect to health and life as well as the inferior creature which, compared with himself, has neither reason nor skill. He will wonder in vain so long as he looks simply at the general fact. He will not wonder at all when he proceeds to an analysis of all the details upon which that general fact depends.

In the first place he will learn from an analysis of the data he may collect, that man is the subject of many more diseases than the inferior animals are; that he suffers from certain diseases of the mind incidental to his possession of a mental organisation superior altogether to theirs, and from which diseases they are exempt; that he suffers from some diseases springing from human vices from which the lower animals are also exempt; that he suffers from some contagious diseases from which they are exempt; that he suffers from some diseases connected with industrial pursuits from which they are exempt; that he suffers from indulgences in certain luxuries of a deadly kind from which they are exempt; that he suffers from various accidents from which they are exempt; that he suffers from hereditary taints of disease from which they are exempt.

Both classes, man and the lower creation, suffer from those primary causes of disease which exist in the form of variations of season, of heat and of cold, and of all those varied changes included under the head of changes meteorological. But here again there is a difference in respect to result. The lower animal, uninstructed, or at least but rudely instructed, in the modes of defending itself from the external elements, lives exposed to the fury of these elements, less the protection

it can obtain in sheltered resorts of natural production, shade of woods and shelter of caves. Man, wiser and more self-protective, outwits the rude elements by building for himself houses and towns, by lighting fires, by making clothes, and by setting, in many other ways, stern nature at stern defiance. It would be a most interesting study to follow out this argument of the value of health and life in man and in the inferior creation, to gather up, as it were, the exemptions from disease and death which might accrue to man if he were simply to put himself, or if he could simply put himself, in the same position in respect to exemption as that held by his lower earthmates. We must not attempt this inquiry. We must be content to study man as regards his conditions of health in the defences which he has built for habitation, and which he calls his cities, villages, and houses ;—his self-invented and self-constructed protections from external influences in their endless variety of change.

In this study man does not appear always on the best side. To the diseases which are assumed to spring from cold and wet, such as catarrhs, attacks of bronchitis, inflammation, and rheumatism, man is more subject than the lower creation. This may be owing to difference of organisation, and may therefore be allowed to pass without comment unfavourable to his ingenuity and practice. But there is something else which must not be allowed to pass, and which is, in fact, the one point of all others calling for our attention.

Man, by a knowledge and skill not possessed by the inferior animals, in building cities, villages, houses, for his protection from the external elements, has produced for himself a series of fatal diseases, which are so closely associated with the productions of his knowledge and skill in building as to stand in the position of effect from cause.

Man in constructing protections from exposure has constructed conditions of disease.—In an age when he could not foresee the results of his own work he created these conditions, and it is not fair to blame him, because he did not, in his primitive days, know better. We do know better now, and it is our fault if we do not improve on the original bad work, rectify it, and remove intelligently the evils which, from deficient intelligence, have been so long perpetuated. This should be the uniform object of the present sanitary scholar.

COMMUNICABLE DISEASES FROM CONSTRUCTION OF HABITATION.

At this early stage of our work, we may look at the more important diseases which have been promoted, and some of them indeed introduced, by the errors of construction that have been developed in the dwellings of our communities. We shall in this way be the better prepared to see the most effective modes of removing what is bad and of introducing what is good, so that the diseases may be prevented.

Typhus Fever.—The most fatally spreading disease which man has introduced into his habitations is that fever which, under the various names of spotted fever, gaol fever, black death, and typhus, has so often committed the most fatal ravages in

crowded towns and cities. This disease might with perfect correctness be called foul air fever. It seems as if it can always be lighted up when numbers of persons are closely packed together in dirty and unventilated rooms, and the history of this country is singularly rich in the records of its origin, dissemination, and mortality. Experiment after experiment has been unintentionally made, during the course of centuries, to prove the effects of close and foul air on the health of the nation. In the last century these proofs accumulated in a remarkable degree. In previous times, though the air of living-rooms and of dormitories was close and noisome, a fashion prevailed of purifying the air by the process of fumigation, or as we would now say, by the plan of using antiseptic gases or vapours. My late accomplished and much-lamented friend, Dr. Francis C. Webb, brought this fact out with singular clearness, by quoting the directions for the suppression of the Plague that were issued from the Royal College of Physicians in the year 1665. The College appears to have thought nothing whatever about the value of fresh air, but its wise councillors directed that "fumes of rosin, pitch, tar, turpentine, frankincense, myrrh, amber," be used, and that "the woods of juniper, cypress, cedar; the leaves of bays and rosemary, to which, especially to the less powerful scented, may be added somewhat of laburnum, storax, benzoin, lignum aloes; one or more of these as they are at hand, or may be procured, are to be put upon coals, and consumed with the least flame that may be, in rooms, houses, churches, and other places."

This antiseptic method of prevention of disease had its advantages; advantages not over the admission of fresh air, but over the plan of excluding fresh air and of using no antidote. In the last century, while the value of fresh air was still but imperfectly known, the value of the antiseptic plan was all but entirely ignored. The bunch of rue was placed,—as it still is in some assize towns, I believe,—before the Lord Judge when he took his place on the judgment seat, and served for him as a disinfectant to the extent of its poor powers. In the prisons no such care was taken, and the result was that in the foul and crowded dens in which the criminals were confined, the occurrence of contagious fever became, I had almost said, the rule, while the propagation of fever from the gaol as the centre of it, was looked upon as a natural phenomenon. The fever passed from the gaols to the houses, and the houses, themselves close and unventilated, nourished it amongst the inmates, as a well-kept conservatory might nourish and develop the fruit of the vine. Nor were the gaols the only servants of the spreading devastating fever. The dormitories of the students of the great universities became also centres from which the fever, having once originated, spread far and wide.

We have to search deep into the history of this present century to see any such change in household sanitation as should exclude the pestilence we may call foul air fever. Since the reform has commenced, the introduction of typhus into a locality, from overcrowding and bad ventilation, has not been of common occurrence, and strangely enough, those places which once were the very foci for the pestilence, the gaols, are now the most free from the danger. Yet I myself remember houses and districts of houses in which this fever was generated, and from which it spread with great rapidity and intensity.

Practically, we have less to fear in these days than perhaps we ever had, of

making our domicilcs the originators and forcing-spots of typhus. Yet it would be to the last degree unwise to forgct the lessons of the past, or to ignore the fact that, in comparatively rare but certain instances, the evil remains. It still does happen that, in places where tho discase may bc least expected to occur, typhus is developed. In the last most striking instance I can recall, where the fever which originated from overcrowding spread widely, a small country village was the scene of the manifestation. A traveller riding through that village would have thought of it, last and least of all, as a seat and centre of the great plague of a past century. Yet it was such, because the conditions for the development of the outbreak were present in the homes of the people.

Relapsing Fever.—Another disease of the true pestilential kind which is connected with bad domestic sanitation is relapsing fever. In some respects this fever resembles typhus, and though, owing to the relapses that take place, recovery from it is more prolonged, it is not so fatal as typhus. The name of "famine fever," which has also been applied to it, may convey the idea that it springs from deficiency of food, and this, in a sense, is true. But it must not be supposed that mere deprivation of sustenance is the sole cause. Another factor again is demanded, and that factor is bad ventilation, the enclosing together in one close room, or cellar, or cabin, of a number of ill-fed persons who, to shut out the cold, shut out the air. In a great epidemic of this fever, of which I was at once a witness and a sufferer in 1847, it was clear to all of us who observed, that bad air was the necessary adjunct of bad or insufficient food. The disease followed where the habitation was most crowded and the air was most impure.

Scarlet Fever.—The common disease, scarlet fever, finds in bad domestic sanitation an ever-favouring condition for its distribution. It would, in my opinion, be incorrect to say that scarlet fever can, like typhus, be engendered by close air. The poison of this disease has an origin distinct of itself, of which we know very little, and once introduced it may disseminate in the most spotless and the purest abode. I have seen it spread, I had almost said with equal foot, in the houses of the best as in the houses of the worst construction, and I know of no standard by which a house could be reported as free from the danger of the entrance into it of scarlet fever. At the same time, when scarlet fever has entered a dwelling, the safety of that dwelling afterwards, its position as a centre of the malady, or its freedom from contagion, turns altogether on sanitation. The poison of scarlct fever, though minutely distributed, is almost certainly solid in respect to its material quality. If it were volatile, like a vapour or gas, it would be more dangerous than it is to the persons who surround the sufferer, and would rapidly lose all its dangers on distribution upon articles of clothing or parts of the house. Being solid, however, it traverses over a limited area about the sick person, but fixes on surrounding objects capable of receiving it, and holds to them until it is destroyed by heat, oxidation, or mechanical action.

The poison may be laid up in a house for months, perhaps years. During my early career, I assisted a medical friend at Saffron Walden, in Essex. In the

district we had a severe outbreak of scarlet fever. At a short distance from one of the villages in the district there was situated, on a slight eminence, a small clump of labourers' cottages, with the thatch in the bedrooms peering down on the beds of the sleepers. A man and his wife lived in one of those cottages, together with four of their lovely children. Scarlet fever entered the door of this cottage, and struck down one of the children fatally. The three others were at once removed to the care of a grandparent, who lived at a village several miles away. Some weeks elapsed, when one of these was allowed to return home. Within twenty-four hours it was seized with the disease, and died with equal rapidity as the first. We were doubly cautious in respect to the return of the other children. Every inch of wall in the cottage was cleansed and lime-washed; every article of clothing and linen was washed, or, if bad, destroyed; floors were thoroughly scoured; and so long a period as four months was allowed to elapse before any of the remaining children were brought home. Then one child, a boy nine years of age, was permitted to return. He reached the cottage early in the morning, was dull the next day, twelve hours later was suffering from malignant scarlet fever, and, like his fellows, died from the affection. In this case I have no doubt that the roof, the thatch, was the part in which the poison was concealed; but whether that conjecture were correct or not, the incident shows, with too much force to be mistaken, how this particular poison may be locked up in a dwelling suitable, from its bad sanitation, for the reception of the poison. The papers on the walls of a room that has been occupied by a person suffering from the disease may become the agent for retaining the infection, though in a less certain degree.

Small Pox.—The same dangers which are connected with scarlet fever in the dwelling-house extend to small pox. The poison of small pox may be retained as a solid particle for an almost unlimited period in a dwelling. It may be enclosed in woollen materials; it may be concealed in adhesive material, on the walls, in the ceilings, on the floors. In the case of this disease we know, of a fact, how the infectious material may be retained. It is a solid particle, and dried up as a mere dust it retains its poisonous properties, so that it could be sent from one part of the world to the other without losing its specific power of propagating its disease. In the old times, before the protective system of vaccination was discovered, and before inoculation became a practice, it was all but impossible to escape taking the malady, for nearly every house became, at one time or another, a home and centre of its poison. To show how easily the poison of small pox is taken up by cotton and woollen materials, it is worth while to relate that, in the early days of the process of inoculation, cloth was used as the means for conveying the poison. In a remarkable paper communicated to the Royal Society in the year 1734, by Dr. Nettleton of Halifax, in Yorkshire, that physician describes how he communicated the disease, from the sick to the healthy, by inoculation. He opened the ripe pustules of an affected person, and having wiped the lancet he had employed on a piece of cotton stuff, he used the impregnated cotton as the communicating substance. When he wished to inoculate, he made a small wound on the leg or other part of the body, and putting over the wound a portion of the infected stuff,

fixed it there for a few hours with a piece of plaster. In this way he introduced the disease, and such, he says, was the effect of the infected pledget of cotton, he often found it merely necessary to wipe the newly-made wound with the cotton in order to ensure perfect inoculation.

Whooping Cough.—The poison of pertussis, or whooping cough, is easily distributed through a house, and retained by substances to which it attaches itself. The poison in this disease is thrown off from the throat, and as, in the violence of the coughing, there is often a wide diffusion of fluid from the mouth and throat, the danger of the spread of the affection is always considerable. It is true that the contagion is not conveyed far, and it probably is not long retained in the active state. I mean that it may be, and possibly is, readily destroyed, by oxidation, after it is thrown off from the sick. At the same time, for a period of at least some hours after it has been emitted it will take effect. Not long since a young lady, who came under my care suffering from whooping cough, was able to tell me where she contracted it. She had been in one place only where it was possible for her to be subjected to the poison, and that place was a shop into which she entered to purchase confectionery. While in the shop, a child of the shopkeeper came in from the back room, and was seized with a violent paroxysm of spasmodic coughing from whooping cough, under which she had been labouring for several days. That sick child communicated the affection, not to my patient only, but to several other persons who came to the place. In one instance it seemed that the poison was communicated from this shop by the bread that came from it—a most likely means of conveyance, seeing how readily the poisonous material, diffused with vapour, would attach itself to the bread-stuffs.

Measles.—The poison of measles may remain for a considerable period in the house, and may attach itself to articles of furniture, clothing, walls, and ceilings, like that of small pox and scarlet fever. I do not, however, gather from my own observations that this poison is so long retained as that of scarlet fever. I should infer that it is a poison more easily destroyed by oxidation than the particle of scarlet fever or of small pox which acts as poison.

Sewer-air Fever.—There is a class of disease which is, or may be, developed in the house, not from the introduction or generation of the poisonous particle of a communicable disease, but from the diffusion through the house of the gases of decomposition which emanate directly from the contents of the cesspool or sewer. The air of a house may be contaminated from the sewer, and the contamination may produce distinct indications of disease, without exciting any one of the specific communicable diseases, such as small pox, typhus, or scarlet fever. This is a fact not generally understood, although it deserves to be thoroughly understood.

In past days the diseased condition here referred to was much more common than it is now, and the affection called by our forefathers in physic "continued fever" was, I feel quite sure, usually dependent on sewer air. I remember myself the disease known as continued fever—a disease which ran an indefinite course, and which did

not spread, but which would attack the inmates of one house, and confine its evils, for the time, there. The late Dr. Barker, of Bedford, was the first to show distinctly and experimentally the influence of sewer emanations, and to prove that they were poisonous when diffused through the air. He produced symptoms of febrile disturbance, with derangement of the intestinal canal, in inferior animals, by exposing them simply to sewer emanations. He made an analysis of those emanations, and determined as gaseous products, common air, carbonic acid gas, sulphuretted hydrogen, ammonium sulphide, and, sometimes, free ammonia. He also investigated the action of these gases severally, and while showing that all of them, except common air, had a distinctly poisonous effect, even as diffused from the sewer or cesspool, the principal agent of evil in them was the sulphuretted hydrogen. The symptoms produced, varying in degree, corresponded in the worst forms of exposure with those of continued fever, and in milder forms of exposure with those of feverish malaria, feebleness, nausea, and want of appetite—symptoms so commonly seen in persons who live in a close room near to a cesspool or sewer, or in a room into which the air of the cesspool or sewer enters.

This subject of impure air from cesspool or sewer emanations extends somewhat more into detail in relation to the causation of disease. Without being "literally" a cause of fever, even in its mildest form, the impure air is often a promoter of dyspepsia, nervousness, and depression, during the presence of which conditions the person affected is, in the strict sense of the term, neither well nor ill.

Typhoid or Enteric Fever.—Some years ago the disease known at present as typhoid or enteric fever was not distinguished from typhus. Typhoid is now recognised as a distinct disease, and has been designated cesspool fever, drain fever, and foul-water fever. It is a disease commonly connected with bad drainage of the house as its cause, but the evidence is not so clear in favour of its making the air the medium of conveyance as is the evidence of such mode of conveyance in the case of typhus. Some physicians are so satisfied that typhoid does not spread through the air, that they are content, in a sick ward of a hospital, to let the typhoid patients commingle with the general sick; and they affirm that the risk is *nil* if ordinary precautions are taken to avoid certain easily specified dangers.

I am inclined, from experience, to hold the same opinion, but this does not render domestic sanitation in relation to typhoid less important; on the contrary, it gives rise to the necessity for additional care and circumspection. If it be true that the poison of typhoid is not borne from one person to another by the air within the dwelling—and it must be admitted that the statement is, as a rule, correct—it is not the less certain that the cesspool or drain is a source of danger, and it may be the prime source. The evidence that has now accumulated, to the extent of being all but a demonstration, is to the effect that the poison of typhoid is thrown off from the affected by the secretions which pass from the bowels. These secretions are poisonous, and if they enter so as to infect the drinking-water or other drinks or foods, through such infection the disease easily passes from the sick to the healthy. It still remains a debatable point whether the

emanations from the excretions of the typhoid patient may not be conveyed by the air if they are permitted to dry upon clothing or other substances, from which, afterwards, they may mechanically diffuse through the atmosphere.

PULMONARY CONSUMPTION FROM DEFECTIVE SANITATION.

One of the most fatal of our English diseases, pulmonary consumption, or consumption of the lungs, has been largely promoted by the presence of unchanged and impure air in the dwelling-house. This fact has been so often observed, it has led some to believe that pulmonary consumption is infectious under certain circumstances, and that living in a room where a consumptive person is also living may be serious in its consequences to those who are healthy. I have myself shown that consumptive persons who have lived in the same apartment have successively become affected by the disease, the following being perhaps the most striking of these facts :—A man, by business a hawker, a "Cheap Jack," who was accustomed to live, with some other members of his family, in the van in which he travelled from fair to fair, and from which he sold his wares, was brought to me in the third stage of pulmonary consumption. He soon succumbed to the disease, and was succeeded in business by his brother, who followed precisely the same line of life, and came to live in the same van. His brother soon afterwards became consumptive, and died. He, in turn, was succeeded by his sister's husband, who shared the same fate; and, not to extend the narrative to an undue length, in the course of seven years I had before me no fewer than nine victims of the fatal pulmonary disease, in every one of whom it seemed to originate in that particular travelling-van. It was in vain I protested to those affected against continuing to live under conditions so favourable to disease. They argued that they were constantly in the open air by day, that they got regular change of air, that they were not exposed to wet, and that at night they were very snug; in short, they would not believe that the sleeping in the van-house had anything whatever to do with the disease.

The observation of a series of facts such as these may at first sight seem to convey the notion that the poison of the disease was conveyed in the van, and was communicated from one series of its occupants to the next. The evidence is not conclusive. The first sufferer had bought the van new, and first occupied it; he, therefore, did not get the disease by a process of continuation. The van was afterwards regularly emptied, cleaned, newly painted, and exposed to the air; so that the probabilities of the continuance of specific communicable poison in it are most remote. The practical truth is, however, none the less valuable that the disease originated so many times under the same conditions, and truths of this kind cannot be too often related.

On a large scale, the fact of the influence of impure air in the production of pulmonary disease was fully brought out in the Report of the Army Commission in 1858 respecting the life and health of our soldiers quartered in England. Before the appearance of the Report, and for some time afterwards—until, indeed, the recommendations of that Report were acted upon—the health of our home-

quartered soldiers was so bad that their mortality was actually double what it ought to have been. The rate of mortality in the effective men of all ages of the army at home was 17·5 in the thousand. At the same time the rate of the mortality of the town and country population at the same ages was 9·2 in the thousand, while that in the country districts only was 7·7. In the population of one of the most unhealthy towns in the kingdom, namely Manchester, the mortality was then very high; but even in this selected spot of unhealthiness it was only 12·4 per thousand of persons of the same ages compared with the 17·5 of the soldiery.

Here was, then, a remarkable series of facts in which contrasts of the most singular kind were established. Nor did the contrasts end as above stated. The soldier's life was a selected life, and ought therefore to have been better than that of the civilian of the same age. It was manifestly much worse, and so the reporters were led to a further analysis. They asked the question :—How does this soldier, selected in consequence of his good life, stand, in relation to life, by the side of the agricultural labourer of the same age? The soldier, they argued, ought to stand in a much better position than the agricultural labourer. His duty is in the open air, he receives an ample supply of food, he is housed at considerable expense; if he should fall sick, the Government stands to him in the place of a friendly society; when sick he is at once sent to the hospital, however slight his illness may be. He has no care for the morrow, and he has all the treatment and all the nursing his case may require. Materially, therefore, the soldier in England had all the advantages of an agricultural labourer, with some other advantages that ought to have assisted his vital powers. How, then, did he stand in respect to vitality? The answer that came out was the startling one that, within corresponding ages, the mortality of the agricultural classes belonging to friendly societies was 6·055 per annum in a thousand, while in the soldier class it was 15·7—namely, 11·1 per thousand in the household cavalry, 13·5 in the dragoons, 17·9 in the infantry of the line, and 20·4 in the Foot Guards.

Some further facts were elicited from a comparison of the mortality of the selected soldiers by the side of men of out-door trades in towns, and men of trades that were partly in-door and partly out-door, and over whom the friendly society did or did not throw its protection; and, again the tale was told that the mortality in these unfavoured ranks was little less than half that of the Foot Guards. Even the printers yielded 9·090 to the 20·4 mortality of the Foot Guards.

When the cause of this great disparity came to be investigated, it was discovered that the diseases known as pulmonary were the fatal maladies which specially affected the soldier, and laid him low. It was discovered that while in civil life the deaths by pulmonary or chest diseases at the soldiers' ages were 6·3 per thousand, they amounted in the cavalry to 7·3, in the infantry of the line to 10·2, in the Guards to 13·8. Of the entire number of deaths from all causes in the army, diseases of the lungs constituted the following proportion :—in the cavalry 53·9 per cent.; in the infantry of the line 57·277; in the Guards 67·683 per cent. Pushing their inquiries one step farther still, the reporters came at last to the kernel of their task. Why should these selected soldiers suffer so specially from diseases of the chest?

Was there anything in their occupation, in their clothing, in their diet, that would account for the phenomènon, and indicate the predisposing causes of their excessive mortality from pulmonary disease. On these points the reporters were able, by the process of exclusion, to remove many suspected causes. They were able to exclude night duty, want of exercise, unsuitable employment, and intemperate and debauched habits. These influences the inquirers did not, of course, ignore, but by comparison they found them insufficient to account for the disparity which was seen to exist between the soldiers and the other classes of the community.

At last they came upon one cause which they could not exclude, and which, in accordance with the Newtonian saying, was both true and sufficient cause to account for the phenomenon. That one cause, or rather that one series of causes, was overcrowding, insufficient ventilation, and nuisances arising from latrines and defective sewerage in barracks. A single agent, *vitiated air*, acted with such intensity—especially when superadded to a certain degree of exposure—as not only to produce in the Foot Guards an amount of chest disease, and especially of pulmonary consumption, greater than was produced in civil life by all the other causes united, but actually to carry off annually a number of men nearly equalling in the infantry, and actually exceeding in the Guards, the number of civilians of the same age who died from all classes of disease.

One final observation crowned this research of the Commission of Inquiry. The Commissioners compared the mortality of the army when it was hutted before Sebastopol in 1856 with that of the troops at homè, and discovered that the mortality before Sebastopol was nearly one-third less than the mortality of the infantry of the line, while it was two-fifths less than that of the Foot Guards barracked in England. The mortality of the army before Sebastopol during twenty-two weeks, ending May 31st, 1856, was, including deaths by violence or accident, at the rate of 12·5 per thousand per annum, as against 17·9 in the infantry, and 20·4 in the Guards quartered in England.

The record of these observations is the best and most forcible, because most extended and accurate, that has ever been supplied respecting the influence of confined air in the living and sleeping apartments of men who are accustomed even to an active life and to the enjoyment of much out-door life. If I, or any other physiologist, had desired to carry out a great experiment in order to inquire how diseases of the lungs might be artificially induced in men who had been healthy up to the time of the experiment, we could not have devised any method that would have led to a series of results more striking or more convincing. Neither could we possibly have concluded our experiment more satisfactorily than was done in the recommendations of the commissioners. They recommended that an entirely new system should be introduced into barrack-life; that air, fresh and pure, should at all times circulate through the buildings, and especially through the dormitories; and that every soldier should have efficient and sufficient breathing-space. Since these regulations have been in force, the English soldier at home has no longer the unenviable position of being first in the ranks of those who fall victims to pulmonary consumption and other affections of the respiratory organs, but is rather the model of a lower mortality; so that as the gaols, once the foci of fever, are at this time

the most free of that disease, the barracks, once the foci of consumption, are now the most free of that destroying malady.

Here we see a scale, as it were, of disease. In the gaol, in its very worst condition of foul air, the disease typhus was the scourge: in the barrack, with foul air, but less foul, consumption was the scourge; pure air substituted in both places, both the diseases have been enchanted away. Lessons such as these should never be cast aside, and they apply with the most telling force to our present work. In many of our best houses—I mean best in relation to their appearance and cost, not in respect to their construction—the errors that were common in the barrack are still present, and rooms are used as sleeping-rooms which stand in the eyes of the sanitarian like so many experimental boxes for the synthetical development of pulmonary disease. The room is too small; the room is devoid of a fireplace; the room is devoid of a ventilator; the room has a window that will open with difficulty, and at best but a little way; and yet that room is used as a sleeping-room for one, or, it may be, two persons. These are the rooms in which they who are disposed to pulmonary affection find their early fates; these rooms are the vestibules to the grave.

It often occurs that these rooms in our modern houses are situated on the top floor of the house, in that part which is set aside for the servants. "These," it is said by those who show the house to the inquirer, or would-be tenant, "these are only the servants' bed-rooms!" As if it were of no consequence where the servants were lodged for the one-third of the life they are in service. Often the tenant, perfectly satisfied with the intimation, is quite content not to inquire any further into such apartments, which are made over, as suggested, to the servants, or in some instances to the servants and to the children of the family. To this neglect very much of the disease of the lungs which we find in the occupants of the rooms is clearly traceable. The barrack lesson, on a small scale, is definitely repeated.

NEURALGIC AND MIASMATIC DISEASES.

The evils arising from close rooms and unchanged air in our modern houses are very much increased by the presence in the air of atmospheric moisture or damp. When damp is present, with even free ventilation or passage of air through the rooms of a house, there is danger of mischief from the damp alone. The damp interferes with the natural transpiration from the skin; the damp becomes the ready bearer of atmospheric impurities; the damp maintains a low temperature, and if the external warmth be great it keeps up an irregular temperature. All these influences combine to make the place unhealthy, without any other factor of disease being present. Life long spent in an atmosphere charged with moisture must be attended with suffering, and the sufferings that are evoked are often most severe. It is in the damp house that those most painful of painful maladies, neuralgia and acute and chronic rheumatism, have their frequent origin; and, again, it is in the damp house that the as yet unknown poisonous material called malarial poison finds its home and its means of increase. We may say that all damp houses are, after a manner, malarious houses. In them the conditions are present in which the morbid

transferable products of all diseases are most favoured, certainly for transmission, and possibly for growth and development.

It has often been suggested that some organic poisons may be condensed from the water which is diffused through the air of the apartments in which persons occupying damp houses and damp localities live. This is, indeed, probable from the known fact, well carried out in chemical experiments on air, that the gases diffused in a confined atmosphere, and the organic matter produced or diffused in the same place, can be condensed and collected in water. Dr. Letheby, in his examinations of sewer air, placed glass globes, holding within them a freezing mixture, in the sewer. The water condensed from the air on to the outer surfaces of the globes was collected from them into a dish beneath, and was found, on analysis, to yield the soluble sewer gases, and various forms of microscopic organic life. In the human lung we possess, as I have shown in my experimental lectures on medicine, one of the most powerful of condensing instruments, and we can but see, when we reflect thoughtfully, that to inhale for hours at a time, or days at a time, a moist atmosphere, containing in its water organic and inorganic impurities, is to be subjected to much danger. If we inhale but ten cubic inches per breath, and by respiring sixteen times in the minute, one hundred and sixty cubic inches per minute, we must soon accumulate an enormous store of soluble noxious substance for entrance into the blood.

Thus an impure damp air is a double source of danger; such air is called malarious, and in such air the great malarious diseases—ague, neuralgia, and rheumatism—have found their fitting homes. Macculloch has shown that such malarious air affects even successive generations of residents in it: that it produces a degeneracy of the races—a fact which is never, he states, better shown than when the inhabitants of marshy plains are brought into immediate contact with a people of the same radical origin and race inhabiting the healthy mountains, or hilly tracts which bound or include them. The stock, he says, not only becomes reduced, but deformities are frequent; while, anatomically, the bones are found to be affected: their extremities in particular being unusually large and spongy, and rickets as a positive disease being also an implicated consequence. In England there was a time when in the undrained marshy districts many of these same evils were present, if not dominant; and although we have, by improved drainage and cultivation of land, created an improvement in the physical condition of the people in the respects named, we have not removed all the evils. Dr. George Buchanan, the present distinguished first health officer in this kingdom, has shown with lucid clearness that consumption is singularly in excess in districts where the humidity of the air is most marked; while rheumatic, neuralgic, and miasmatic affections may still be every day locally connected with damp dwellings, if they be carefully and properly investigated.

In our modern towns and cities, and in the newest parts of them, many sources of damp are encountered. In the construction of some modern dwellings bricks are used which will absorb, as Mr. Edwin Chadwick has shown, as much as a pound's weight of water. For laying the bricks, mortar is sometimes used in which sand containing sea-salt forms a constituent part; in the portions that are constructed of

timber, wood that has been brought across the sea and has been saturated with sea-water is sometimes employed. When these errors of construction are introduced in the building of a house, damp is a necessary result. In wet weather the building materials are easily saturated with water, and the fires within bring out a free diffusion of water vapour. During the dryer seasons, while the house is drying, the warmth that is external causes still a diffusion of vapour; and if the house be for a short time left dry, it is ready upon a return of rain to absorb again, and, like a sponge, take up so much liquid to create damp as before.

In houses of the kind named the evidence of damp is at almost all times present. The walls are seen to be damp; or paper upon the walls is observed to be peeling off or to be loose in places; or there is a patch here and there of saline encrustation; or there is moisture on bright objects, such as the mirrors, and rust on steel grates, and other polished metallic surfaces.

I have met with houses of this faulty construction so often, I fear they must be more general than is commonly supposed. In a large and fine hotel where I was recently destined to sleep, I found the bed-room so charged with damp that the large looking-glass over the mantel-shelf was dimmed with moisture, and though it was late in the night, I would not sleep until I had kindled a large fire, and produced some degree of dryness in the air. In hotel establishments, it is these damp rooms, much more frequently than damp sheets, that provoke cold, fever, and rheumatism.

Into our small and, to the eye, pretty suburban dwelling-houses, off the large towns, the same errors creep, and perform a deadly mischief. I once visited a new and pretty row of houses in a London suburb to see a young lady there who was suffering from pulmonary consumption. The house was literally saturated with moisture. This patient died from the disease that had been lighted up into activity there. On making further inquiries, I found that in the same row of houses, twenty in number, there occurred within the first two years of their occupation six other instances of pulmonary consumption and fourteen instances of acute rheumatic fever. A patient who was once under my care, and who was a confirmed cripple from rheumatic disease following upon acute rheumatic fever, gave me, in language as simple as it was truthful, the history of her case at its origin. Newly married, she and her husband bought a new house, which, in their desire to settle quickly, they inhabited while the walls were still bedewed with moisture. She sickened with acute rheumatic fever, and never fully recovered from its effects. Worse than all, every one of her children—and she gave birth to seven after her attack—were affected with rheumatic disease, three dying from heart affection dependent upon the rheumatic constitution.

A lesser degree of moisture in a dwelling than is sufficient to produce the above-named acute and serious diseases may be sufficient to cause much painful suffering. In a large number of instances neuralgia and sciatica are either induced directly, or are greatly promoted by residence in a damp house.

Dampness in a dwelling may be due, not to a fault in the materials of which the house is built, but to the position of the house itself. The fine old mansion built in the stagnant valley, or on the margin of a piece of ornamental water or

lake, is too often an illustration of this fact. A veritable superstition now and then haunts such a mansion. So many of the young who are nurtured there die in early youth, that the house is said to have a bad name—it is a house of ill-fortune: it kills its young. About such a house no one is well; the occupants altogether are pale, subject to colds, coughs, neuralgias, rheumatisms; they say the place is "rheumatiky," which is but another mode of expressing that the place is damp.

One reason why damp is so severe and special an evil was briefly explained when the condensation of soluble gases and organic substances was referred to. There is another and purely physiological reason why humid atmospheres injure the body. Low barometrical pressure, excess of humidity of air, and a temperature low, but not low enough to compensate for increase of animal heat by abstraction of it from the body, are the conditions for a febrile state of body, without regard to actual absorption of organic poison. Hence we find that in those months of the year when the air is most humid, the diseases of an inflammatory and febrile character are most predominant, and that even surgical operations are then followed with a higher mortality.

COLDS, CHILLS, AND IRRITATIONS.

The habitation is sometimes a cause of disease in consequence of the body being exposed in it to colds and chills, the effects of irregular temperatures and draughts. The precise nature of a common cold is still a mystery. It is a nervous disturbance, in which the circulation of the blood through the glandular system of the skin or mucous membrane is disturbed, so that the parts affected, first rendered dry and irritable, are afterwards subjected to a profuse excretion and discharge. There are seasons of the year, there are conditions of the air, in and during which the tendency to take cold is very much increased; increased, as it is believed, by some physical change in the atmospheric sea itself. There are conditions in a house which may add to this tendency, and which may perhaps induce the cold, even when the general tendency is not at hand. There are, moreover, some persons who are extremely susceptible to colds, from variations of temperature affecting the external surfaces of their bodies.

In the house, the prevailing mischief is the "draught," as it is called; the passage of a current of air sharply across the body, so that the part of the body that is exposed to the draught is disturbed in respect to the balance of its circulation. Many diseases of an acute kind thus originate from draught. The balance disturbed on the exterior of the body, there is after disturbance in the circulation of the organs within the body; of the lungs, of the kidney, of the intestinal tract. The lungs are the parts which most readily suffer; and congestion of the lungs, ending in bronchitis, in pneumonia, and, in those who are disposed to the disease, pulmonary consumption—phthisis pulmonalis—are the too-often and serious resultant diseases.

In large houses the danger of draughts is less than in small. There is, indeed, no more difficult problem in this uncertain climate of ours than the problem of at

once ventilating a small room properly and of warming it properly, without draught.

Local irritation, affecting the air-passages of the lungs and of the surface of the skin, is sometimes induced by the practice of warming the air of a room by means of a stove made of cast-iron, which stands out in the room, and presents a large and active heating surface. The air, beating on this surface, is rendered dry and very unwholesome, and I have known instances in which persons, from occupying a room the air of which was heated in such a manner, have suffered from cough and even from spitting of blood. It is usual in rooms permeated with this dry air to distribute moisture by having cups of water placed on or near the stove, so that vapour of water may diffuse into the space. The practice is a bad one, because there is no regularity about it. At one time there is abundance of water vapour in the air, at another time not sufficient; and when the stove rapidly cools down, the air is left cold and damp. Thus the relief which the water renders in one direction is lost in another, and the remedy becomes as bad, if not worse, than the evil.

ENFEEBLEMENT FROM DEFICIENT LIGHT.

The political mistake which was once made in this country, in an age utterly ignorant of all sanitary science, of putting a tax on light, had an effect on healthy architecture which was disastrous to an extent little understood. It was an act actually criminal in its ignorance, and we see the effects of it to the present hour. Pure light is as essential to health as pure food and drink. We are but just beginning to understand its vital value. Still, we now do know that those who are immured in dark places become etiolated, or blanched, anæmic, feeble. We are beginning to know more than this. We are learning that by the action of light the poisonous organic products which produce disease are decomposed, or rendered inactive. I found this to be the fact in respect to the poison of the cobra di capello, which poison retained its active properties in the dark, but lost them on exposure to the rays of the sun.

MALAISE AND PHYSICAL FEEBLENESS FROM DETERIORATED AIR.

In addition to the injuries to health from air rendered impure in the modes which have been described above, there are others of a minor character which, though less acute and alarming, are deserving of close attention. In some early researches of mine respecting the action of oxygen gas on animal bodies, I made a series of observations which indicated that air may be deteriorated by the respiration of animal bodies, even though the known products of respiration be completely removed from it. I discovered that if a warm-blooded animal were made to live in an atmosphere of pure oxygen gas it would soon cease to continue in its natural state of active life, although the atmosphere in which it breathed were cleared, in the most careful manner, of the deleterious gases which pass off in its expired air. The discovery was not a new one in science, for the same phenomenon had been witnessed by Sir Benjamin Brodie and Mr. Broughton in their experiments. But

by carrying my inquiries a little farther than theirs, I detected that, in order to produce the depressing effects which follow the long-continued inhalation of oxygen gas, it is necessary that the animals should continue to live in the same chamber of gas. If the gas, being freshly made at all times, were passed through the chamber containing the animals, freely and in current, then the only changes that occurred were a quicker oxidation of the body, an increased waste, and an extreme desire for food: conditions that were much intensified when the temperature of the gas was raised from 60° to 70° Fahr. I also found that after the oxygen had become deteriorated by being retained in the chamber, its vital properties could be restored to it by the simple process of passing electrical sparks through it, provided always that the carbonic acid and other products of animal combustion were carefully removed. I still further observed that in the oxygen deteriorated by respiration, dead organic substances decomposed more readily than they did in fresh oxygen, or in oxygen after it had been electrified.

In another set of experiments with electrified oxygen, I ascertained that when a dead animal substance had undergone decomposition it could be made sweet, and could be temporarily checked from undergoing ordinary decomposition, by the process of subjecting it to the influence of electrified oxygen. Some clotted blood that had been allowed to decompose until, from the formation of ammonia, its solidified fibrine had re-passed into the soluble state, was subjected to a current of electrified oxygen, and thereupon became so changed that it was deodorised altogether, and re-assumed the solid or coagulable form.

To air deteriorated in character I have given the name of devitalised, and I have ventured to infer that when in close rooms, impure dwellings, and crowded assemblies, we feel or see depression, drowsiness, and, it may be, faintness, there is more at work to cause these effects than the products of respiration or of burning fuel or gas; and that the supporter of animal life, the oxygen itself, is under a physical change of condition, by which it is losing its special sustaining faculty, and is becoming, by negation, a poisonous agent.

If my views on this important subject be correct, devitalised air plays a leading part in the production of much of the low condition of health that marks the inhabitants of overcrowded cities and houses. It is this air, with no vegetation to purify it, which is called the "close air" of the town, as distinguished from the "fresh air" of the country; it is this air which makes the child of the town so lax, pale, and feeble; it is this air which gives to some of our public institutions, where many persons are herded together, the peculiar odour which has been so often and so characteristically called the "poor smell."

The great causes of devitalisation of the air are organic exhalations given off from animal bodies or extricated from organic substances undergoing change. These, by their presence as well as by their diffusion, by contact with the oxygen of the air as well as by admixture with it, induce the bad sustaining state of the atmospheric oxygen. In whatever house there is an odour of what is known as staleness, there is this bad air. In lumber-rooms, where all sorts of incongruous articles are stowed away in gloom or darkness; in under-stair closets, where clothes and shoes are kept; in bed-rooms overstocked with furniture and covered with heavy carpets, which hold

in their meshes pounds and pounds of organic dust; in dining-rooms, in which the odour of the last meal is present until that of the next meal varies it, and from the sideboard or cupboards of which the smell of decomposing fruit or cheese, or other kind of food, is emanating; in drawing-rooms overstocked, to an extreme degree, with furniture, over-curtained and over-carpeted, and through the air of which the scent of dead flowers is constantly diffusing; in kitchens, in which the odorous indication of cooking is perpetually present; in sculleries, where it would occur to a stranger, whenever he might enter, that there is then and there a process of washing-up actively going on, and where the products of decomposition from stewed-up bones, potato-parings, recent vegetable green food, with smells from the sink of water poured from greens, are systematically passing off; in passages and corridors, loaded on their walls with the dried skins and feathers of dead animals, or covered on their floors with worn-out mats or dirty matting, and in which the air is always close and dusty; in libraries, where the books are piled to the ceiling, and on the shelves and volumes of which dust accumulates day after day, until a book has to be flapped clean of dust before it is usable; in smoking-rooms, where at all hours the fume of stale tobacco is ever present: in each and all of these places the air is devitalised, in each and all of these places the air is changed in physical quality, and life is not fully sustained. In such places, to use a common expression, not perhaps here found to be applicable in a strictly experimental sense, but still sufficiently applicable to be generally correct, the oxygen is reduced in power. It is being used up for the final destruction of organic substances, which are, in a health point of view, inadmissible into the air of the dwelling-house.

The evidence of this impure air is rendered in many striking ways, but particularly by the presence in the house of the lower forms of life. When flies during warm weather are specially attracted to a room; when "mould" collects quickly on the walls; and when, in the room, edible substances soon become mouldy, then it is certain that the conditions of health are not properly fulfilled in that room. The same observation may be made to extend to what are more distinctly known as vermin. A house that is infested with any kind of verminous insect is not possibly a healthy house. It is a house that tells its own tale. That living thing which disgusts the senses by its presence does so because the senses are the outworks of the body: because in them the sentries of the body are on guard so vigilantly, it may be said that everything that offends the senses in a marked and definite degree offends the body altogether and the life. There is little excuse even for ignorance to be unhealthy.

Persons living in deteriorated conditions of the air are not, of necessity, marked out as suffering from any definite form of disease. They are not so ill as to require a doctor, and many of them go on for many years without complaint, and without admission that they are sickly in the ordinary sense of the word. Others are always suffering from malaise without being laid up, but they are seen to be pale, easily wearied, dull in spirit, and when they have once tasted it, anxious and longing for pure air, and specially for the air, ozonised and fresh, that sweeps over the sea and is tasted on the sea-shore. The good that is done by sea breezes to people who live in large towns is conferred on those chiefly who, within the

precincts of town or country, are stived up in close houses redolent with the reduced and impoverished air that springs from dust, decomposition, smoke of tobacco, or other similar disturbing agency. The occupants of all classes of houses in cities feel, I believe, the oppression somewhat; but those who protect themselves from the deteriorated air to the fullest possible extent, who are able to live and breathe in light and spacious apartments, and who keep their apartments clean, feel little need, by comparison with others less favoured or less careful, for sea-side or country residence. They suffer chiefly from the smoke and other much more widely-diffused agencies which fill the out-door spaces of the city, and which, though provocative of some derangements of body, are not always at work, and when at work are much less severe than the spoiled and impure atmosphere within the dwelling.

It deserves also to be mentioned in this place that in the house in which the air has been subjected to influences leading to its devitalisation, the effect for evil is much increased when the epidemic-producing poisons are introduced. It is not necessary, neither is it correct, to suppose that in a house where the air is deteriorated the specific poisons of the specific diseases will of themselves originate because the house is in the bad state here indicated. But certain it is that houses which are charged with impure atmospheres are the places in which the septic diseases are most likely to be intensified, and in which they are most likely to spread. The physician who enters an unwholesome house into which one of the spreading diseases has found an entrance is quickly made alive to the extra dangers that exist in such a dwelling, is particularly guarded in the matters of opinion he is asked to give, and is doubly cautious in respect to the due carrying out of measures that are of a preventive nature.

It is most probable that in past times, when all our great centres of life were dens of impurity, and when the air in all parts was reduced in vital value, the whole community was subjected to the bad influence, and sometimes suffered from it. Sydenham, and other classical medical writers and fine observers, according to the lights that were at their command, have been wont to use the term "epidemic condition of the air" to explain the general spread of great epidemic outbreaks or pestilences. By this they suggested that pestilence depended on some unknown and undefined state of the air. I suspect they were right and wrong: right in supposing that a condition of a peculiar kind affecting the air was present when the epidemic was present, and necessary as sustaining the epidemic itself; wrong in assuming the condition as the originating cause of the disaster. In our day we should more correctly reason that the bad state of the air might exist for years without an outbreak of epidemic disease, but that the poisonous particle of a disease of that kind being introduced, the outbreak was favoured and made irresistible.

It is possible, moreover, I had almost said probable, that the great atmospheric sea itself may, over large tracts of it, become so changed, that, without any necessary errors on our part, it may be rendered incapable of sustaining the vital capacities of men and animals to the full or natural degree, and that thereupon there may be, as the old men wisely said, an epidemical atmosphere, in which, in the absence of contagion,

there may be experienced much lassitude and general ill-health, without more acute symptoms, and in which, in the presence of poisonous particles, organic spreading diseases may assume a general instead of a local course, and a severe instead of a modified type. The peculiar, I may almost say the specific effects of an east wind, a wind which eats, as it were, into the body, and lowers the whole vital energies, is a fitting illustration of what I mean, though it is not absolutely a correct illustration according to our present knowledge. In such an air we know, practically, how some diseases, like asthma and bronchitis, are favoured in their development and course, despite all artificial modes of warming and other counteractives. But here our knowledge ceases; how the air influences the body guarded from its direct effect, and seemingly safe from it, we cannot in any way explain.

ACCIDENTS FROM INORGANIC POISONS.

The air of a room may be deteriorated by another means; namely, by so lighting or heating the room that minute products of the decomposition of the material that is burning or has been burnt are diffused through the air. In the process of lighting a room by gas, the effects to which I now make reference are most prominent and common, and may therefore be cited as typical. When gas is burned there is given off from it, in addition to sulphurous acid and carbonic acid, minute portions of carbonic oxide, an extremely deadly gas. The carbonic acid gas that is given off is hurtful when it is present in the proportion of one per cent., and is dangerous beyond that amount. The carbonic oxide is fatal when in the proportion of one part per thousand, is productive of very dangerous results when in the proportion of one in five thousand, and is productive, as I found by experiment, of distinct effects when in the proportion of one part in fifteen thousand, even if it be breathed, with interruptions, for a period of ten to fifteen minutes.

It is also worthy of note that when the carbonic oxide gas is absorbed into the blood, by respiration, its effects do not pass away at once on withdrawing from the gas. Some gases and vapours, which are very deleterious when inhaled, such as carbonic acid, for example, are quickly set free from the blood when the person who breathes them is removed from their influence. To make a plain but comprehensive explanation, they do not adhere to the blood on their way to the tissues and the great organs of the body. Their effect is, therefore, transitory. They affect while they are being taken in; they soon cease to affect when they cease to be taken in. Other agents, being very readily soluble in water, are absorbed by the water of the blood, and linger for a time in the body, and keep up some short temporary disturbance after they cease to be supplied to the body; but their action is also temporary, for being soluble and being volatile, they are steadily carried out of the body in the fluid excretions and by the breath. Carbonic oxide plays a much more lasting part when it enters the economy. It combines, as oxygen does, with the red blood corpuscles, and it forms with them a new compound, which changes the course of nutrition so definitely that the organs of the body make new products. Thus I discovered, many years since, that if carbonic oxide be for a short time inhaled, even in minute quantities, the disease known as diabetes is temporarily set

up: that is to say, such a change is produced in the economy that glucose (grape sugar) is made in the body in so large a quantity that it escapes from the kidney by the fluid excretion of that organ, carrying with it an undue or unnatural flow of water.

The bad effects of inhaling an air charged with the products of combustion from common coal-gas are mainly due to carbonic oxide. The prolonged headache, the flushed face, the quick pulse, the loaded tongue, the copious secretion of urine, and the succeeding languor, lasting for some days after such inhalation, are traceable directly to this potent cause.

The effects of carbonic oxide are sometimes shown, after it has been delivered into houses or public places, from the coke-furnace or stove. In the year 1856 the late distinguished Dr. John Davy, brother of the still more distinguished Sir Humphry, recorded in the pages of my "Journal of Public Health" an accident of this kind, which was attended with most serious consequences. On the 6th of January, 1856, there assembled in the new church at Ambleside a large congregation. The church was of such a size as to have sittings, without galleries above, for over 900 persons; it was lofty, open to the very rafters, and had a cubic capacity equal to about 150,000 cubic feet. The warming apparatus consisted of a stove placed in a crypt under the chancel at the east end, and of a single flue, communicating with the open air, and running through the basement floor of the building under the middle aisle, in which were three grated openings for allowing the air, heated by a cockle, to pass, two of which, the western ones, were open, the third, the eastern, closed. In consequence of the apparatus affording an inadequate supply of heated air, precautions were taken to confine the heated and exclude the cold air; the windows were all closed, as were also the doors, after the commencement of the service, only one having been opened previously, and that to leeward.

At the time, the atmosphere was in a state not favourable to the diffusion and dispersion of smoke or vapour, but rather to its stagnation and accumulation; the sky was overcast with dark, low clouds; the little wind that there was was southerly, and so mild was the day that bats and insects were abroad, and were seen on the wing between one and two o'clock in the afternoon.

At the commencement of the service there was an unpleasant smell perceived, like that from coal-tar, or of smoke from an ill-burning fire, and when the sun shone, which it did at short intervals, its light was peculiar, from the hazy quality of the vaporous air; but no apprehension was felt of anything injurious, nor was any alarm excited till towards the end of the communion service, when, one after another, children and young people began to go out from feeling unwell, the numbers rapidly increasing, till, shortly after the commencement of the sermon, the alarm became so general, almost amounting to a panic, that the minister thought it necessary to abruptly bring his discourse to a termination, when, though there was no rush to the open air, there was no delay on the part of any one present from seeking it. Of the scene outside, from the many sufferers, some prostrate, some in danger of life, and variously affected by the noxious air they had breathed, it would be difficult to give an idea. Hardly a person, out of a congregation of probably

400 at least, did not feel more or less unwell, or was not alarmed on account of a child or near relation seriously affected.

The most robust of mature age, of both sexes, experienced least bad effect: little more than headache of some hours' duration. Those who experienced the worst effects were children and young delicate women. Vomiting was a common symptom in the former, and was attended with great prostration of strength and feebleness of the heart's action, and a tendency to fainting. Those who threw up the contents of their stomachs were the soonest to recover. Tremor of the hands and feet, with diminished sensation, threatening paralysis, occurred in many instances of the latter. Oppressed breathing, with uneasiness or pain of chest, was pretty commonly experienced. Next to the very young and delicate, those advanced in years and the plethoric seemed to be most affected.

Apart from age and constitution, position, that is, in relation to the openings of the flue, was not a matter of indifference in regard to the severity of the symptom. Those suffered most who were nearest the openings, especially at the west end, where the majority of the children, belonging to the Sunday-school, were seated, not in pews, but on open forms, so that nothing screened them from the flow of the vapour in their direction. That there was an accumulation of the noxious agent in this portion of the church was indicated in a visible manner when the doors towards the west end were thrown open, by the stream of thick misty air which then rushed out.

Of those affected, the greater number were pretty well before the following day. In a very few instances the indisposition produced continued, but gradually diminishing, for several days. In one of the most severe cases, a young lady of about seventeen, the recovery was not complete for nearly a week, and hardly then. She fainted in the attempt to walk home, was afterwards hysterically convulsed, had a feeling of extreme feebleness and languor, with oppression and pain of chest, and loss of appetite. In a large number of other instances something similar occurred. The maximum of noxious effects was experienced after leaving the church and going into the open air.

Of the organs affected, the lungs, the heart, and the nervous system appeared to bear the brunt of the effect. In no case were the bowels deranged, and the stomach and voluntary muscles probably only sympathetically. The one instance in which attention was given to the premonitory symptoms and to the progress of the morbid action was that of a delicate boy, aged about twelve. His mother, who sat by him, noticed his incessant yawning, and this for a considerable time before he was taken ill; he became so ill and suddenly enfeebled that he required to be carried out.

After describing that the effects in this case were clearly due to diffusion of carbonic acid and carbonic oxide in the air, Dr. Davy states that he was minute in description, in consideration of the importance of the subject—that of warming public buildings, and the too little attention commonly paid by architects to a matter involving risk of life. He tells us that "in the contract for building the Ambleside church the mode of warming it was not even noticed in the specification, and though the flues were made under the superintendence of the clerk of the

works, it was without the knowledge of his principal. Further, in illustration of the want of due attention to this important object, owing to the chimney of the stove and of the vestry fireplace terminating above the belfry and in the open vault of the spire, the ringers on more than one occasion had been sufferers from the noxious gases descending on them, which could hardly fail of happening in a calm state of the atmosphere.

The want of precaution as regards obtaining artificial warmth by fires is of very wide application, owing, undoubtedly, to ignorance as much as to carelessness. Patent fuel is advertised, fit, as vaunted, for use in stoves in passages and rooms without chimneys, as if the carbonic acid and carbonic oxide gases produced were respirable and innocent; and it is, no doubt, bought and employed with that belief. How often do we hear of lives sacrificed from burning charcoal in huts and tents? It was one of the many causes in operation in the destruction of life amongst our troops before Sebastopol, which ordinary care and science should have excluded."

In conclusion, Dr. Davy adds, that if such morbid effects as have been described, endangering life, can take place in a church so capacious as that of Ambleside, and holding at the time less than one-half its full complement of people, how much greater must be the risk when a like mode of heating is employed in smaller, more confined, and crowded buildings, whether public or private?

There is another source of danger in relation to the presence of carbonic oxide gas in the dwelling-house, and that is from the insidious escape from pipes or taps of coal-gas itself in houses that are lighted by it. When coal gas escapes in free quantities, the peculiar odour it emits very fortunately discloses the danger, and leads those who are exposed to it to take prompt measures to prevent the escape and to change the air. All this is as it should be: the odour of the gas is a safeguard. There remains, however, more to be told. Coal-gas contains from seven to eight per cent. by volume of the inodorous carbonic oxide. Whenever, therefore, coal-gas escapes into a room, even though it be in such small quantities as not to be directly detectable by its odour, it becomes a source of danger.

This fact was well illustrated lately in my own house, and in the library in which I am at the present moment writing. The library is of good size. It has a cubic capacity of 6,000 feet, and it is fairly ventilated, although improvements are yet wanted in that direction. Some weeks ago I began to suffer from peculiar symptoms. I felt at times drowsy during the day without any apparent reason, and soon upon that I had a sense of nausea and giddiness, followed by a sense of coldness of the body, feebleness, and inaptitude for work. At first I imagined that these symptoms were due to derangement of the stomach or indigestion; but this did not fully account for them, and in a day or two I noticed that they invariably came on in the library, after I had been sitting in it for an hour or so, and that they were soon relieved when I went out of the room. At last the addition of another symptom led me to feel sure that the air of the library was the source of the mischief, and that I was suffering from the effects of inhaling carbonic oxide. I compared the symptoms I was now undergoing with those I experienced when inhaling carbonic oxide in experiment, and I had no doubt as to the identity. There was but one source for carbonic oxide in the place, and that was the coal-gas.

In the room at large there was no odour of the gas. We sought for escape of gas from the burners of the chandelier and from the pipes leading to it, but without result. At last, on opening a small cupboard at the lower part of the room, in the corner to the right of the fireplace, a faint odour of gas was perceptible, for the moment, after the door of the cupboard was opened. This recess was below the book-shelves, and there was no supply of gas anywhere near to the spot. A further search was therefore carried out in the basement below the library, and ultimately it was discovered that a small portion of gas-pipe passed over a partition wall, between the upper part of the wall and the ceiling. On cutting down to that concealed pipe—the existence of which had not been suspected—it was found to leak, and a minute jet of gas was detected issuing from it into the space above it and into my room. Entering into the room at the base of a large set of book-shelves, it diffused behind the books and gradually into the air, not in sufficient quantity to be detectable by the senses, but in quite sufficient quantity to be detectable by one who happened, from the result of exceptional work, to have experimented with it, and to have learned, by this purely exceptional experience, the action of one of its constituents on life and health. Had I been a man of letters or business merely, I am sure that, failing to understand the cause of the very unpleasant symptoms which I felt, I should have consulted a physician, and in all probability should have suggested a case the nature and cause of which would have remained in extremest obscurity.

I dwell on this question of carbonic oxide and its action on the body at great length, for the simple reason of its immense practical importance. We cannot be too much alive to the existence of an agent so easily generated, so readily diffused, so subtle in its action, so injurious in its effects.

IRRITATIONS FROM METALLIC POISONS AND DUSTS.

Irritations, leading to much irregularity of health, may be induced in the household by the diffusion through the air of it of minute particles of dust, and of certain dusts which are derived from metallic coverings on surfaces of walls, or of walls and ceilings. Whenever a room is dusty, it is unhealthy. When a room is packed with furniture that is capable of holding and retaining ordinary dust, it is unhealthy. Every time such dust-holding furniture is trodden upon or pressed by being sat upon, a small cloud of dust is given off. The dust may not be visible; it may require actually a beam of the sun to be able to render it, or, more properly speaking, the light, visible. But the dust nevertheless is there, and if we could irradiate our rooms with a strong beam of sunlight, I suspect that most of us would be startled to see what an atmosphere of dust we take into the lungs each time we breathe the air of what many would call a model house.

It is fortunate for us that we are provided with an apparatus of a minute ciliary kind, which is ever at work in the bronchial tract, sweeping it out as it were towards the mouth by myriads of infinitely minute brushes, and preventing

the particles of dust from entering the ultimate or vesicular parts of the lungs. It is equally fortunate for us that the greater portion of the inorganic dusts are insoluble, so that, although they fall on the mucous surface of the lung, they are not absorbed by that surface and carried away into the circulation. Thus, as a rule, we escape the bad consequences arising from dusts in the air we breathe; they traverse a certain length of the respiratory tract; they are wafted back into the throat; and they are then swallowed and disposed of in the stomach or other part of the alimentary canal.

There are, however, some dusts which, being metallic in character, soluble, and poisonous withal, are not so innoxious as the common inorganic dusts. It has become a custom since the introduction of the fashion of covering the walls of rooms with various coloured and beautiful papers to use arsenical substances for the purposes of colouring. Green papers have thus become specially objectionable, and the green flock has in some cases been a veritable source of danger. It has also been shown by Dr. Leonard Sedgwick that papers coloured blue, and which heretofore have not been considered as charged with arsenical substances, may still contain arsenic, and become poisonous to the air.

The bad effects arising from the presence of dusts in the air of the dwelling-house are largely confined to those which spring from arsenical dusts. In factories, mines, potteries, corn-stores, flour-mills, and metal-grinding workshops, in rooms where rags are sorted, and in rooms where pearl-grinding is carried on, the mechanical injuries from the inhalation of irritating dusts are serious. But in the house the most appreciable evils are from arsenical dusts. I do not mean to say that the inhalation of ordinary dust is harmless. Far from that. The dense dark colour of the mucus expectorated from the throats of those who breathe a dusty or smoky atmosphere itself attests that such an atmosphere must be obstructive to natural respiration, and, as a matter of course, injurious. It is also fair to suppose that the feebleness and unhealthiness of persons who live in atmospheres of dust are, in part, due to such exposure. But, on the whole, the evils that are distinctly traceable are, mainly, those which spring from the arsenical particles which float in the air of rooms covered with arsenical colours. The symptoms are those of irritation of the conjunctival membrane of the eyes, of the mucous membrane of the nose, throat, and bronchial passages, and in very bad cases, of the mucous membrane of the stomach, bowels, and bladder. The skin is occasionally affected.

PRINCIPLES OF DOMESTIC SANITATION.

The intention and object of domestic sanitation is so to construct homes for human beings, or if the homes be constructed, so to improve them, that the various diseases and ailments incident to bad construction may be removed to the fullest possible extent. The diseases need not be looked upon as necessities of existence, but may be recognised as results of ignorance, or as accidents which, though they may not spring from sheer and wanton ignorance, are removable by accurate, foreseeing, and all-providing knowledge.

(1) The first principle in the construction of the healthy house is to put into it, for building purposes, and for furnishing purposes, as little as possible of all substances that hold and retain those specific particles of disease, which being set free, spread by diffusion, and excite their specific diseases. Thus, in all constructions porous materials are bad; absorbing materials are bad; materials such as thatch and straw for roofings are bad. In furnishing, woollen and fluffy materials are bad; heavy curtains to beds and windows are bad; carpets which cover the whole of a room are bad. In a word, all materials that catch dust, keep dusty, hide dust, and on being shaken yield clouds of dust, are bad.

(2) The second principle, and it is a basic principle in domestic sanitation, is to take care that everything that is generated in the house and that is of an excretive, offensive, and injurious form, shall be prevented accumulating in the dwelling. Whether it be dust or refuse, or remnants of food, or sewage, it is necessary that it be removed as it is produced. The foundation of this principle is laid in the drainage of the house. Unless a house be so drained that it is absolutely cut oft from the sewer into which its contents are discharged, it is not a healthy home Unless a house be so drained that the emptying of its sewage is an immediate process, so immediate that as the sewage is poured forth it finds its way from the house direct into the sewer, the house is not a healthy home. It will be shown in the future pages of this work that this perfect regular cleansing of the house is just as easily attainable as is the fatal plan of making the house its own sewer.

To carry out perfect drainage it is essential that all pipes leading into or from a house should be within ready reach, and should always be open to inspection at various places in their course. The main soil-pipe should at all times, where it is possible, be on the outside of a house; it should be open at the upper part, and, under proper arrangement, it should also be open at the lower part; but if it be impossible to have a pipe outside the house and readily accessible there, if the pipe must be inside the building, so much the more important is it that it should be throughout its course in sight, and so accessible that at any moment it can be reached. To enclose a soil-pipe in a wall in such a manner that it can only be examined after days of work and a vast amount of costly destructive mischief, is the worst plan that can be adopted. Clear throughout its entire course, the pipe should also be open to the air at the top, and in the lower part or basement of the house should be made to enter a space which in its turn is open to the air, so that the collection and retention of gases is impossible anywhere, and so that any pressure of gas is equally impossible.

Care must eventually be taken in respect to the drainage of the house, that the contents discharged from the sewer be carried away by the escape-pipe from the house in the most perfect and rapid manner. All intercepting catch-pits, all and everything that can by the merest accident hold and retain the sewage, must be completely rejected. Equal care must be taken that the soil-pipe running from the house into the sewer shall not itself become like a sewer, from being too large to be completely flushed. As a rule, a pipe four inches in diameter is of sufficient size to convey away all the contents of an ordinary house; of a house, for example, that can

comfortably accommodate ten persons. For a house used as a dwelling-house only a six-inch pipe is sufficient for a family of any size, the rule being, *cæteris paribus*, that the smaller the tube the more complete and certain is the flushing and cleansing. The pipe properly selected in respect to its size should be laid in such a manner that it is open at both ends. It should start from the open space into which the descending pipe from the house pours its contents, and outside the house, before it enters the sewer, it should have an ascending branch communication with the open air. When these precautions are used, there can be no accumulation of sewer-gas and no pressure of gas between the descending pipe and the sewer.

Lastly, the utmost care should be taken to make the pipes that convey the sewage from the house perfect in and throughout their course, so that there shall be no leakage by the way. The sewer-pipe should be as perfect in this respect as the coal-gas pipe. Up to the present time that result has not been achieved, though we are now making close approaches towards it. I leave it with the essayist who shall specially treat of this part of our work to decide what material is best for the soil-pipe,—earthenware, iron, glass. My impression is, that iron, or glass of sufficient strength and well jointed, would be by far the best material. It would be impermeable and lasting, and glass would show the facts of obstruction and accumulation wherever they might occur.

The tube running from the descending pipe into the sewer ought always, when it is practicable, to be carried outside the dwelling, and in entering into the sewer from the house it ought to be securely trapped between the opening immediately outside the house and the sewer. The best traps for this purpose will be described in a subsequent chapter.

To Mr. Rogers Field, C.E., and others, we are much indebted for improvement in systems of house-drainage; and I have seen a house after it had been drained by Mr. Field as entirely cut off from the sewer and from sewer emanations as if it had been set on a mountain-side and had been drained into the open air at a distance from it. So ought every house to be drained. It is criminal to let disease enter any house by that hitherto grand staircase for disease—the passage from the cesspool or common sewer.

(3) A third principle in the construction and arrangement of the healthy house is to have it so built that it shall not hold damp in any part. All the materials used in building should be compact, dry, and impermeable to wet. The wood should be sound and well seasoned, the bricks or stones should be free of porosity and power of absorbing and retaining water; the plaster on the walls, and all the substances with which the walls are covered, should be firm and impermeable. The idea that a surface which shows damp and allows water to trickle down it is a bad surface because it illustrates the fact of damp so decidedly, is a false idea altogether, for if an absorbable surface were there, there would be none the less damp, but a means by which the existing dampness would be concealed. Every external source of damp should also be provided against. The space round the base of every house should be open for some feet from the walls, and the drainage of the space be made complete. Every leakage from

drain or pipe should be effectively closed, and the flow of water from the roof be carried off in a manner that shall prevent accumulation on the roof and in the passages by which the water is conveyed away. In a word, the appearance of damp anywhere in a house, whether it show itself by direct evidence of moisture, by rust, by mould, is sufficient to indicate that the house is not in a condition compatible with the existence of health within its walls.

(4) A fourth principle in house sanitation is to ensure the full admission of light. There ought not to be a dark room in any human habitation. It is all but impossible to let in too much of the sun. As a rule, a south-western light is most desirable, inasmuch as that light feeds the dwelling for the greater portion of the day; but no such advantage as would come from the possession of that source of light should prevent the admission of it from other aspects. It should be kept steadily in mind that the light not only makes all clear that should be clear, but that it purifies, and that when it cannot be directly admitted into a room, it should be admitted by being reflected from a good reflector. In planning windows the utmost care ought to be taken that they are of sufficient size, and that they are not overshadowed by overhanging architecture, or obscured by the smallness of the panes and the excess of the framework.

The plan of introducing coloured glass into windows as an ornamentation admits of little objection if it be not overdone, and if the places and colours be carefully selected. Blue is a good colour to admit if it be not dense, and green much softened is unobjectionable. Red is rather painful to the eyes after a time, and yellow interferes so much with the chemical action of light it ought never to be introduced into windows of a dwelling-house. In the main, the points of practice in lighting are,—purity of light, light from all points of the compass when it can be had, and abundance everywhere.

(5) A fifth principle in the construction of the healthy home is to secure pure and warm air, free distribution of it through every room, perfect means for allowing escape of air that has been used, and such sufficient means for warming air that it shall not, by creating irregular currents, be a cause of cold draughts. In considering how these advantages are to be secured, it is well to keep generally in mind the following general rules. In every dwelling-room twenty-four square inches of space should be allowed for each person as an admission space for air. The same should be allowed for exit space. Air should always be steadily admitted, whenever it is practicable, from the outside of the house, through a conduit, to a chamber at the back of the fire-stove; and, warmed there to 60° to 65° Fahr., it should pass by a separate conduit towards the upper part of the room, to be admitted through the wall into the room. Captain Galton's stove answers well for this purpose, and in building new houses there should always be a special construction for admitting warm air. Again, the basement of the house should be so arranged that the air from it should not ventilate into the upper rooms to stagnate there. Through every roof there should be an efficient opening into the air to act as a pure ventilating-chimney

for carrying away the mixed atmosphere from all parts. Bed-rooms should be specially well ventilated and warmed equally.

On the whole, the chimney-draught forms the best exit from the sitting or sleeping room, and the Arnott exit valve into the chimney near to the ceiling is efficient. The air should be admitted either by the Galton stove, or by the window on Dr. P. H. Bird's method, or by the Sheringham valve, which opens from the outside at the upper part of the room, or by the Tobin tube. For drawing-rooms specially, Mrs. Priestly has lately invented a very simple and elegant method of ventilation. This consists in making a double window half way up the window-space, the half window being composed of two light folding glass doors. Between these doors and the sash of the window flowers are placed, and when the lower sash of the window is raised a little distance, the air passing up through the flowers ventilates over the half window-doors into the room. In constructing new houses provision ought to be made for bringing in the air-supply from the upper part of the house, from the outside roof down through the house into each room. I have modified an old house so as to bring this improvement into perfect action.

(6) The last grand desideratum in the house is the supply of pure water. Properly, the water-supply ought to be constant, so that storage of it within the dwelling is unnecessary. When that is impossible, the cistern which receives the water should be left as open to the air as it can be, should be made of slate or galvanised iron, should be often emptied, and frequently cleansed. The plan of placing the cistern out of the way, so that it is difficult for a man to get into it to clean, and so that it becomes charged with foul air from any source, is most objectionable and dangerous. With the best cistern the water ought to be well filtered after it is drawn—a process which is, I think, preferable to that of having the filter permanently within the cistern.

SUMMARY.

I have now endeavoured to give an outline of general domestic sanitation. I have striven to show what deadly foes may be bred within the habitation, how they may spread in it, and how they may be retained within its walls. I have tried to indicate what are the essentials in a house for keeping it free of the deadly enemies that may spring up in it, and for maintaining its perfect salubrity. I have shown that the healthy house, be its construction, and I may add, be its architecture, what it may, must have for its charter of health the following seven points.

It must present no facilities for holding dusts or the poisonous particles of disease; if it retain one it is likely to retain the other.

It must possess every facility for the removal of its impurities as fast as they are produced.

It must be free from damp.

It must be well filled with daylight, from all points that can be charged with light from the sun, without glare.

It must be charged with perfectly pure air in steady changing current.

It must be maintained at an even temperature, and must be free of draughts.

It must be charged with an efficient supply of pure and perfectly-filtered water.

A house possessing the advantages named under these heads cannot be far from a perfected healthy house. It is a house in which disease will never be generated, so long as it is kept up to its proper standard. It is a house in which disease, if it be introduced, will remain for the briefest possible period. It is a house which, after disease has left it, will admit of instant and complete purification.

The details of such a dwelling in all its purity I leave for description to the learned writers who are to follow.

ARCHITECTURE.

By Percival Gordon Smith, F.R.I.B.A., and Keith Downes Young, A.R.I.B.A.

CHAPTER I.

SITE AND ASPECT.

Contaminated Sites—Subsoil—Absorption of Soils—Ground Air—Disease often due to Site—Drainage—Prevention of Exhalations—Aspect—Light and Wind.

The site for a house is one of the most important points that has to be considered by any one about to build. Whether he contemplates an ordinary dwelling-house, a town residence, a suburban villa, a labourer's cottage, or a country mansion, the question of site calls for the utmost consideration.

Until within a recent period there has been far too little attention paid to this important subject. Indeed, it is only within the last few years that public attention has been generally directed to it. This has been done in the provinces by the model building regulations, issued by the Government, in 1877, for the guidance of Local Sanitary authorities in framing bye-laws as to new buildings in their districts; and in the metropolis by the bye-laws made, in 1879, by the Metropolitan Board of Works.

It is well known that where proper regulations do not exist, builders and others occasionally dig out from the site of a new house good materials, such as sand, gravel, brick-earth, or other substances that have a marketable value, and cause the excavations so made to be filled in with any rubbish that is available—often not of the sweetest kind. This is obviously liable to be highly prejudicial to the wholesomeness of the house that is to be built over such materials.

It is, however, not artificially-made sites alone that are to be regarded with suspicion. Almost every natural soil needs some precaution before it can be regarded as really fit to afford a thoroughly wholesome site for a house. Many persons are in the habit of regarding a gravel soil, particularly if situated at a considerable elevation, as affording a perfectly wholesome site. Such a soil undoubtedly has some important advantages; but it ought not to be overlooked that even when the gravel is naturally very compact, there are innumerable pores or small cavities between the particles of sand and stones of which it is composed. This is proved by the quantity of water that a dry gravel will instantly absorb, and which has been found to be sometimes equal to as much as one-third of its bulk. In the same way some natural rocks are almost as porous as gravel; for it has been ascertained that some of the best building-stones will absorb as much as five or six per cent. of their weight of water, and chalk will take from thirteen to seventeen per cent.

It will, therefore, be readily perceived that the subsoil of a house, if dry, may

contain in its pores, or air-spaces, a vast amount of air; or, if it be not dry, a very considerable quantity of water, or moisture. When it is considered, moreover, how common it is for drains to be defective at the joints, and thus to let sewage continually percolate into the ground, and for the conditions of ashpits, middens, manure heaps, &c., to be such that there is constant soakage going on from them into the ground to an extent far beyond the deodorising power of the earth which receives it to render harmless, it will be seen how extremely liable is the subsoil of a house to become contaminated. Professor Von Pettenkofer says :—"The ground round our houses is far more contaminated by the ashpits, privies, cesspools, &c." (and he might have added drains) "attached to them than a churchyard is by the bodies in it which have six years and even longer for their decomposition, and have a far larger area in which to decompose than the organic offal of the houses in a thickly inhabited town."*

It has been said that some soils are more or less absorbent than others. Thus the granitic, metamorphic, and trap rocks, and the hard millstone grits are very dense, and consequently, where they are sound and have not been disintegrated by weather, they do not retain moisture. Some of the limestone rocks are also very dense, but the dolomites or magnesian limestones frequently contain a good deal of water. The clays, marls, and alluvial soils are retentive of damp, and are always liable to be cold, and conducive to fogs. In elevated situations they are, of course, less objectionable than when lying low. Clays, however, are not without advantages, inasmuch as their peculiar density prevents the leakage from drains and cesspools from percolating far into them, though, in consequence of their being sometimes more or less mixed with gravel, or being traversed by fissures or otherwise not of uniform texture, they are not always to be relied upon in this respect. Clay, however, from the amount of alumina to be found in it, possesses considerable powers of deodorisation, which is in itself a valuable property.

Inasmuch, then, as almost every soil is more or less porous and damp, it follows that the interior of any building will, unless special precautions be taken, be liable to be affected by the exhalations rising up from the ground on which it is built; for these exhalations will either rise up by their own buoyancy, or they will be drawn up out of the ground by the warmth of the interior of the house or the draught up the chimney flues. This ground-air, under various conditions, may contain a large quantity of carbonic acid, or it may be full of watery vapour, or be contaminated by reason of its emanation from ground impregnated with sewage or other filth. In any case, it would be extremely unwholesome; and when it is remembered that most people engaged in business daily pass from fifteen to twenty hours, and perhaps more, shut up within houses, it is not to be wondered at if their health suffers from continually breathing an atmosphere polluted in any of the ways just described.

Instances are not wanting to show that certain diseases are actually caused by unwholesome conditions of site; and the occupation of houses in which damp or other pernicious exhalations rise up from the soil on which they are built will have the effect of increasing the severity of many diseases, and of retarding the process of recovery therefrom. Thus phthisis, or consumption, as it is popularly termed,

* "Cholera: how to Prevent and Resist it," by Dr. Max von Pettenkofer, translated by Thos. Whiteside Hime, A.B., M.B., &c., 1875.

has been known to be greatly reduced in towns where the water of the soil has been artificially removed, while it was not reduced in other towns where the soil had been allowed to remain wet. Dr. George Buchanan, in his valuable report on the distribution of phthisis as affected by dampness of soil,* shows very conclusively that wetness of soil is a cause of phthisis to the population living upon it. Similar observations were also made by Dr. Bowditch of Boston, United States, as the result of an inquiry into the causes of consumption in Massachusetts, where that disease is said to be even more fatal than in England. The Registrar-General for Scotland, in his seventh annual report, referring to Dr. Bowditch's inquiries, says: "It was found that the towns, villages, hamlets, and houses which were situated at or near undrained localities, or were on heavy impermeable soils, or on low-lying ground, and whose sites were consequently kept damp, had a very much larger number and proportion of cases of consumption than towns, villages, hamlets, or houses which were situated on dry or rocky ground, or on light porous soils, where the redundant moisture easily escaped." It is necessary to bear in mind that this tendency to phthisis is mainly due to the fact of the population living upon damp soils—not out of doors in the day-time, in active employment, but shut up in their houses during the many hours of night, as well as in confined work-rooms by day, with the moisture from the ground beneath stagnating in the interior of the building.

An interesting instance illustrative of the extent to which a particular disease, when epidemic in a locality, was intensified by dampness of soil, is related by Dr. Blaxall, in a report upon an outbreak of scarlatina, which took place at Swindon in 1879. Dr. Blaxall explains that Swindon consists of two distinct towns, under different sanitary authorities, one being Old Swindon, situated about a mile from the Great Western Railway Junction, while New Swindon, as its name implies, is the town that has sprung up in recent years in the immediate neighbourhood of the railway. Old Swindon lies at an elevation of perhaps one hundred feet above New Swindon, and is situated on the oolitic limestone and sand of Portland, while the subsoil of New Swindon is chiefly Kimmeridge clay. New Swindon was formerly much subject to floods. The two towns are in close contiguity, and the populations, together numbering upwards of 20,000 inhabitants, necessarily have much intercourse.

Dr. Blaxall shows that measles, whooping-cough, and pneumonia—diseases specially affecting the respiratory organs—were far more fatal in New Swindon than in Old Swindon, those diseases having been present in more or less severe form at various times since 1870. He shows that during six years preceding his investigation the death-rate from measles in New Swindon was as much as twenty times that in Old Swindon; from whooping-cough, considerably more than double; and from pneumonia and bronchitis, one-third as much again. The two towns differ very little socially, but topographically Old Swindon possesses many advantages over New Swindon, notably in its comparative elevation, and in the nature of its subsoil. Hence Old Swindon is far drier than New Swindon, a fact that Dr. Blaxall had specially brought to his notice by the sad condition of the floors of some of the houses in New Swindon; and he is led to the conclusion that the increased severity of the diseases above referred to in New Swindon over Old

* Tenth Report of the Medical Officer of the Privy Council, 1867.

Swindon was probably chiefly attributable to the dampness of the subsoil on which the houses in the new town are built, together with a complete absence of precaution to prevent the exhalations from the ground rising up into the houses.

When it is remembered that the above-mentioned rates of mortality represent a vastly larger rate of illness, and, what is of scarcely less importance, impaired energy, it will be easily understood what a serious effect upon the inhabitants of a district may be produced by inefficient precautions against the rising up of moisture and ground-air into the buildings they occupy.

In all soils the dryness of the ground will depend to a great extent on the elevation of the site, and upon the ordinary level of the ground-water in the district. The variation in the ground-water will frequently be considerable in the course of several seasons, and will depend very much on the rainfall, or the proximity of a river or stream, and the facilities for the natural drainage of the soil by its perviousness, and the degree of inclination, or dip, of any subjacent impervious stratum. The ground-water, however, need not necessarily be regarded as itself a source of danger; but inasmuch as it affects the moisture of the superincumbent earth, it promotes or retards certain organic changes in the soil which may be more or less productive of unwholesomeness in the house that is erected on it.

It will be seen from the foregoing remarks that the question as to how the sanitary dangers of the subsoil of a house can best be avoided is one involving most careful attention. These dangers most ordinarily arise in either of the two following conditions :—(*a*) Where an artificially-made site is composed of the deposit of unwholesome matters; and (*b*) where the site is naturally porous and emits moisture or unwholesome air. In the first of these instances it will be obvious that, whatever may be the character of the natural subsoil, the proper course to adopt is to remove the unwholesome matter that has been deposited on the site before any part of the house is commenced. The second instance may involve rather more structural or engineering skill.

If the site is liable to actual wetness at any season of the year, it will, of course, be necessary to effectually drain it. This is specially likely to be necessary where the position of the site is such as to receive the land drainage from a higher level. The drains used for this purpose are ordinary unglazed pottery field pipes, laid in trenches of various depths, according to circumstances, and laid beneath stones or pebbles, in order to let the water soak down and into the pipes. In laying these drains it is desirable that their outfall should be into some open water-course, so that it may be visible and open to the air. If they are laid so as to discharge into the ordinary house drains, or into any sewer or cesspool, it is specially necessary to guard against the entry into them of sewer-air or cesspool-air; and for this purpose an arrangement of ventilated traps will have to be adopted, and in any case ample ventilation of the land drains would be desirable.

The most important point, however, is to prevent exhalations from the soil rising up into the house, and this is best secured by entirely covering the site of the house, within the external walls, with a layer of some impervious material, such as cement concrete, asphalte, or other such substance. Concrete is, perhaps, the most generally available material for the purpose, inasmuch as the materials for making it of a sufficiently good quality can be obtained almost everywhere without

much difficulty. The layer of concrete should be at least six inches thick, and be rammed solid, and when it has been well grouted with liquid cement, its surface should be floated over with cement, so as to make it tolerably smooth and capable of being swept clean before it is finally covered up with flooring; for it usually happens that shavings, sawdust, and rubbish of all kinds, often fouled by the workmen, is swept down under the floor just before the house is complete, and this should of course be avoided.

The surface of the concrete may with much advantage be asphalted, or stone flagging may be laid down upon it with almost as good results. Any of these materials can, if desired, form the finished flooring of the lowest storey of the house, thereby effecting some saving of cost, and giving a not unsatisfactory floor for many purposes. Such a floor has the advantage that, if properly formed, it is practically free from cracks and crevices, which in the ordinary wooden floor of kitchen offices afford such safe retreats for black-beetles and other vermin which commonly infest the lower storeys of dwelling-houses.

Intimately connected with the subject of the site for a house is that of aspect and prevailing winds, for although, in the case of the majority of houses, these are matters which are ordinarily beyond control, on account of the limited extent of the plot of ground on which the house is to be built and the line of frontage which has to be observed, the question should nevertheless be carefully considered whenever the conditions permit of any choice being exercised. In the case of a house standing in its own grounds of a few acres, or of a mansion standing in its park, the aspect is of course a matter of first importance. The house has to be so placed on its site as to command the best views from the principal rooms; and scarcely less important is it that it should be placed so as to form a pleasing object as seen from a distance. It may even be worth while sometimes, before the exact position is finally decided on, to erect a few scaffold-poles and hoardings to mark the size and shape of the house, in order to judge of its general appearance from a distance.

Some of the rooms will need a brighter light than others, and, therefore, where the circumstances will permit, it is necessary to consider how the house shall be placed as regards the points of the compass. In our climate, where the weather is so changeable, it becomes necessary to take advantage as much as possible of whatever sunshine may present itself, and hence those rooms where it is most needed will have to be placed towards the east, south, and west. The consideration of this subject, however, will be dealt with later on, when the arrangement of the several rooms of a house is being discussed.

As regards the direction of the prevailing winds, this can frequently be detected by observing the way in which the trees and shrubs in the neighbourhood are grown. They will generally be found to indicate by their shape the direction of the prevailing wind. The continued pressure of wind in one direction will bend the trees in one way, and the young twigs and leaves on the side on which the wind most frequently impinges get damaged and destroyed more frequently than those on the other side, where the trees are able consequently to grow more freely. In determining the position for the house, it may be of advantage to so arrange it that any smell from the kitchen offices, or from water-closets, &c., shall ordinarily be blown out of rather than into the house.

CHAPTER II.

WALLS AND FOUNDATIONS.

Foundation—Footings—Damp and its Prevention—Damp-courses—Areas—Hollow Walls—Other Methods of Protection from Rain—Thickness of Walls—Bond—Flint Walls—Concrete Walls—Half-timber Walls—Terra Cotta—Party Walls—Dangers from Fire.

THE walls of a house have to be constructed on a sufficiently solid and substantial foundation, to prevent them from sinking into the ground or settling, which usually causes them to crack. They have also to be formed of sufficient thickness to secure a due amount of stability. The external walls of a house, moreover, have to be so constructed, and to be formed of such materials, as to exclude the weather. In the case of adjoining houses, the walls separating one house from the next, known as "party walls," have to be of sufficient substance and so arranged as to prevent not only the transmission of sound, but also, what perhaps is their chief function, danger of the spread of fire from one house to the next.

The stability of a wall depends first upon its foundation, and secondly upon its thickness in proportion to its length between lateral supports, and its height.

In forming the foundation for a wall, it is important that the ground should be excavated to such a depth as to secure a solid bed of natural earth or rock that is not liable to be affected by the weather. All soils are changed by continued exposure to the weather, and even hard rock becomes disintegrated and unsound for a few feet below the exposed surface. Some soils, again, are apt to expand and contract within a few feet of the surface, according to the condition of the weather, being specially affected by changes from continued dry weather to wet and frosty weather. This is commonly the case with clay soils, and unless the foundations of the walls are taken down to a sufficient depth the building is very likely, sooner or later, to show signs of settlement, either by cracks in the walls, or by the doors and windows sticking and the locks failing to fasten properly.

The most ordinary and modern mode of forming the foundations of the walls of a building is to rest the walls upon footings, and the footings upon a continuous bed of solid concrete. The thickness of the concrete for this purpose will necessarily depend very much on the weight of the superincumbent structure, and also upon the nature of the ground beneath it. The concrete ought always to extend beyond the greatest width of the footings of the wall, and should never be less than twelve inches wider—six inches on each side—than the greatest width of the footings. The depth or thickness of concrete should in no case be less than eighteen inches.

The footings ought to be, in height, equal to at least two-thirds of the thickness of the wall immediately above them; thus, if the wall at that point be eighteen inches thick, the height of the footings should be not less than twelve inches, or four courses of brickwork. The footings ought also to project on each side at least half the thickness of the wall at its base; thus, in the case again of an eighteen-inch wall, the footings at the widest part would be three feet in width, and the concrete beneath them would be four feet in width. (See Fig. 1.)

Of course, where the foundations would rest upon natural beds of solid rock, the concrete would be wholly unnecessary, and a modified course of footings would suffice, but the accompanying illustration shows the arrangement that is most usually found necessary.

It is not uncommon with speculative builders in the neighbourhood of London and some of the large provincial towns, to merely remove the surface earth for the depth of about twelve inches, and to commence the wall thereon without any concrete whatever, and with indifferent footings. As this is a most improper mode of construction, it would be desirable for any one who is intending to purchase a new house, or to advance money upon it, to require the ground to be opened in a few places, so as to lay bare the foundations of the walls, to show how they have been formed.

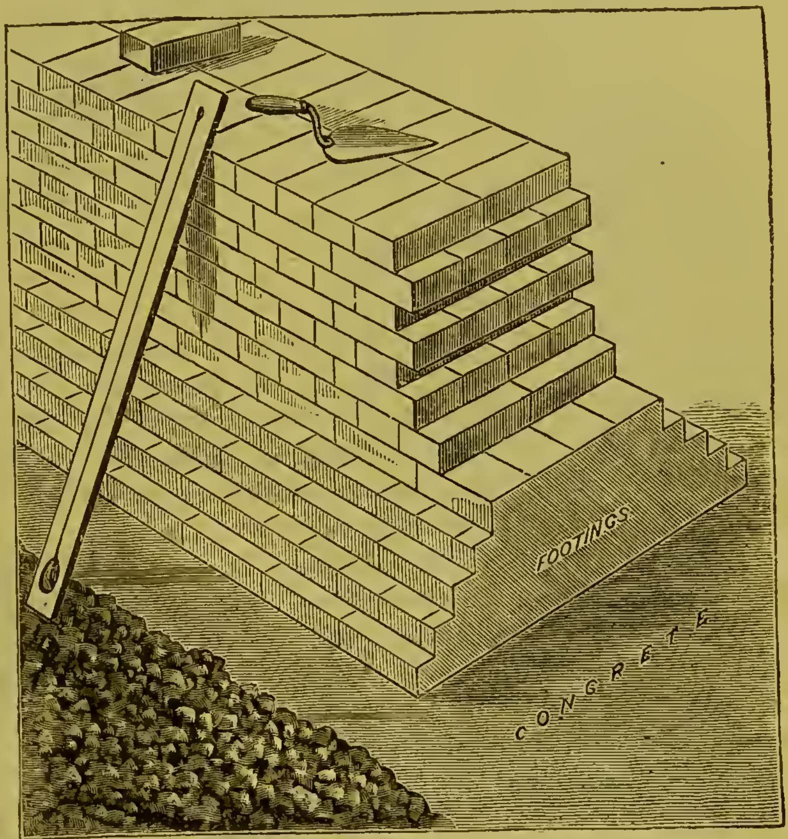


Fig. 1.—Footings.

Having now described the precautions that are necessary for securing efficient foundations, the next point that calls for attention is the method to be adopted to prevent moisture from being absorbed by the material of which the walls of a house are built from the adjacent earth, and, by capillary attraction, rising up in the wall, and thereby damaging the wall itself, rotting the timbers of the flooring, injuring the paint and internal decorations, and polluting the atmosphere within the house.

It is not uncommonly supposed that moisture rises only from the base of a wall, and that a horizontal layer of waterproof material inserted in the wall at a short distance above its base, even though below the level of the ground, will serve to keep down the damp. This, however, is a very serious mistake. Where the wall rests on a proper foundation very little, if any, moisture will be absorbed in it from beneath. Moisture is far more liable to enter a wall from the earth against the sides than at any other point, and it will rise therefrom according to the wetness of the earth and the absorbent properties of the materials of which the wall is constructed. The remedy for this is to place a damp-proof course of some material that is impervious to moisture in every wall of a house, slightly above the level of the ground which adjoins the walls. Various materials are used for this damp-proof course, such as

sheet lead, two or three layers of slates bedded in cement, or a half-inch or three-quarter inch layer of asphalte. Certain bituminous felts are sometimes used, but it is very doubtful whether they can, in any circumstances, be regarded as altogether satisfactory and permanently efficient. Slabs of glazed stoneware (Figs. 2 and 3) are frequently adopted, and are found to answer admirably. They are generally perforated, so as to afford an air-passage through the wall, which, apart from the primary object of the slabs, is most useful in affording ventilation to the space under the flooring, while at the joints the perforation serves to break the vertical continuity of the mortar or other material in which the slabs are set, and which might otherwise afford a means for the rising of moisture. These slabs are made in different thicknesses, from one and a half inches to three inches, and of widths to suit the various thicknesses of brick walls, and they are admirably adapted for their purpose.

Fig. 2.—Patent Damp-proof Slab.

It has already been stated that the damp-course, to be of real use, ought to be slightly *above* the level of the ground adjoining the wall, but it sometimes happens that a house has a basement storey, or a half-sunk basement storey, so placed that if the damp course were inserted in the manner described, it would be considerably above the level of the floor of the rooms in that storey, and thus the walls for a certain height in those rooms would be affected by moisture, and the floor timbers liable to rot. This is by no means an uncommon occurrence, and it needs special arrangement in order to render this part of the house satisfactory in this particular. The most efficient method is to excavate an open area round the house, so as to remove the earth from against the wall (Fig. 4), taking care that the bottom of the area is well below the level of the floor, so that the damp-course may be beneath the level of all the floor timbers, in order to protect them from the injurious effects of moisture. When an open area is impracticable, which may be the case sometimes on account of proximity to a street, or of the extra expense that would be involved, what is called a "dry area" (Fig. 5) may be formed. This would have the same effect as an open area, but its construction need not involve quite so much cost. It is simply an area of sufficient width to keep the moist earth away from the wall, and is covered in at the top. If from any cause neither of the above arrangements can be adopted, there is yet a third method (Fig. 6) of effecting the object, namely, by forming the wall, so far as it is below the level of the adjacent ground, with a cavity in it. In this case it will be necessary to have two damp-courses, one below the floor timbers, and another in the outer part of the wall a few inches above the

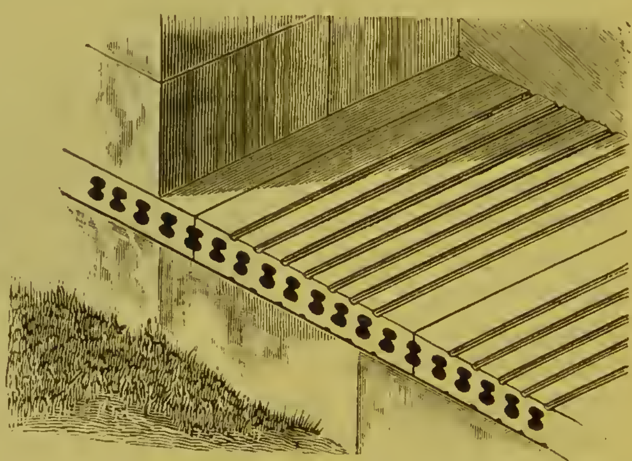


Fig. 3.—Patent Damp-proof Slab.

level of the ground. A similar result is sometimes sought to be attained, though with varying success, by coating the outside of the wall, where it is below the ground level, with asphalte or other impervious substance.

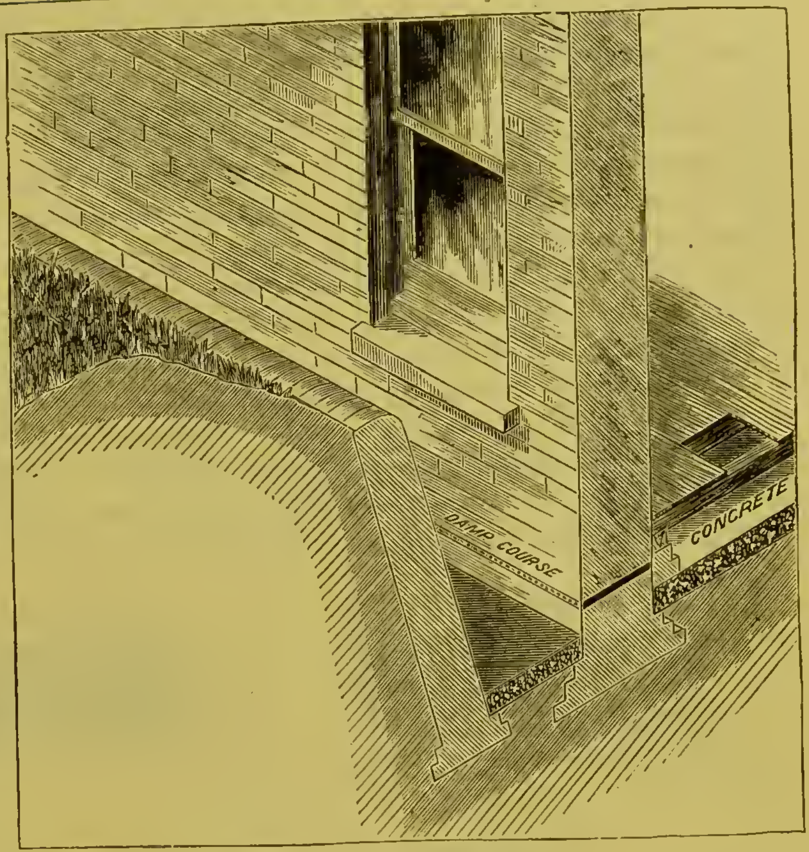


Fig. 4.—Area.

It will, of course, be necessary to provide means of draining the open area, and also the dry area and the cavity in the wall; and in the case of the dry area and the cavity it is specially necessary to provide ample means of ventilating those enclosed spaces. A wise precaution, and one that is, in exposed situations, an absolutely necessary one, is the provision of a damp-course just above the point of junction between the roof and the chimney-stacks.

It is not only necessary to take precautions against the rising of damp in the

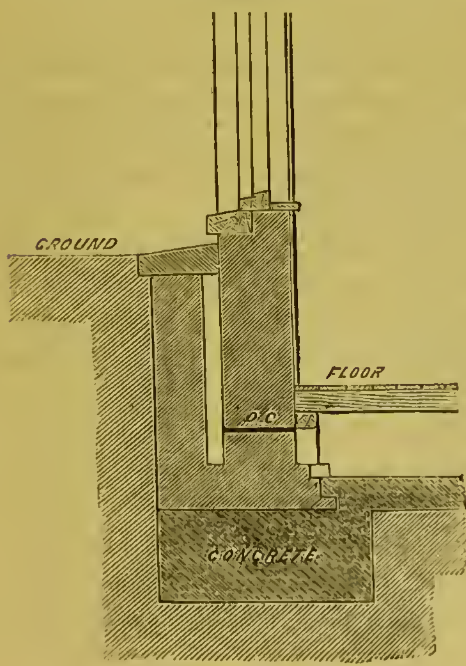


Fig. 5.—Dry Area.

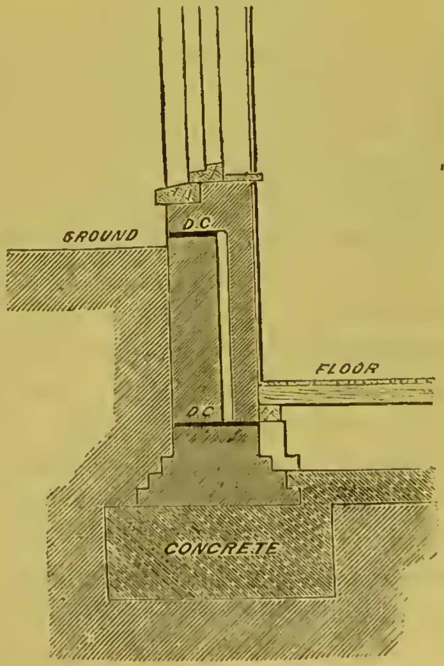


Fig. 6.—Hollow Wall.

walls of a house from the adjacent ground, but the possibility of moisture being driven through the external walls has to be met, and likewise of damp descending from the top of a wall, where, in the form of a parapet, it may be exposed to the weather.

The penetration of the walls of houses by rain during continued wet weather is very common when the house occupies an exposed situation, and it becomes a matter of the utmost importance to secure efficient means of averting this serious inconvenience. Various methods are resorted to. Thus at Brighton and other places along the south coast, in former times, it was customary to face the exposed fronts of houses with a kind of glazed tile, made and fixed with a uniform surface, so as to imitate bricks. Sometimes the outside of the walls is covered with ordinary slating; for small houses and cottages the walls are periodically pitched. Portland cement, however, has superseded many of these contrivances, and is now very generally used as an external coating to the brickwork, and is almost impervious to driving rain. Sometimes the outer face of the wall is covered with a superior

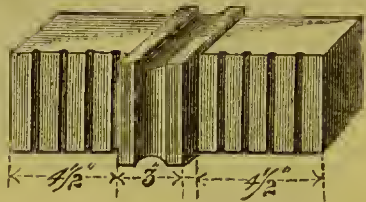


Fig 7.

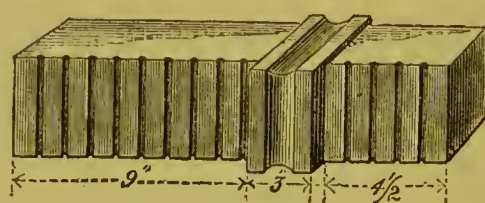


Fig. 8.

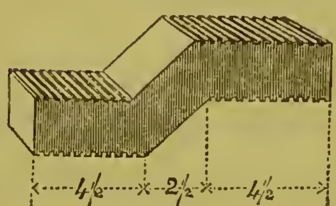


Fig. 9.

Fig. 10.

Fig. 11.

mortar, on which are sprinkled shingle and small pieces of flint—a description of work known as "rough-cast" work. In the convalescent hospital at Seaford—a new building—it was found that the walls were inadequate to keep out the driving rain, especially when exposed to the sea. The remedy adopted was the application of Szerelmey's paint, which is said to have proved successful.

Where it is desired that the brickwork should remain exposed, it is a common practice to construct the external wall with a cavity—that is, to form it of two parallel walls, about two or three inches distant from each other, and tied together by bonding-ties of some non-absorbent material, such as iron or glazed stoneware. These walls, when carefully built, are nearly as strong as solid walls, and they not only protect the house from the penetration of damp from without, but they tend to the maintenance of an even temperature within the house. It is important in constructing such walls to provide a sufficient number of bonding-ties, in order to effectually bind the two thicknesses of the wall together. For this purpose the ties ought to be not more than three feet apart horizontally, and eighteen inches apart vertically. The annexed figures represent some of the kinds of bonding-ties in ordinary use. Figs. 7, 8, 9 are patent stoneware ties; 10 is a wrought-iron tie; and 11 a cast-

iron tie. The stoneware ties possess some advantages over the iron ties, inasmuch as they are not seriously affected by damp. The iron ties, however, ought always to be coated with some protecting material, such as tar and sand, the sand being necessary to assist the mortar to adhere to them, or they should be galvanised. In Fig. 9, the sloping part in the middle is intended to conduct any water that may get into the cavity away from the inner part of the wall, and the bend in the iron ties has

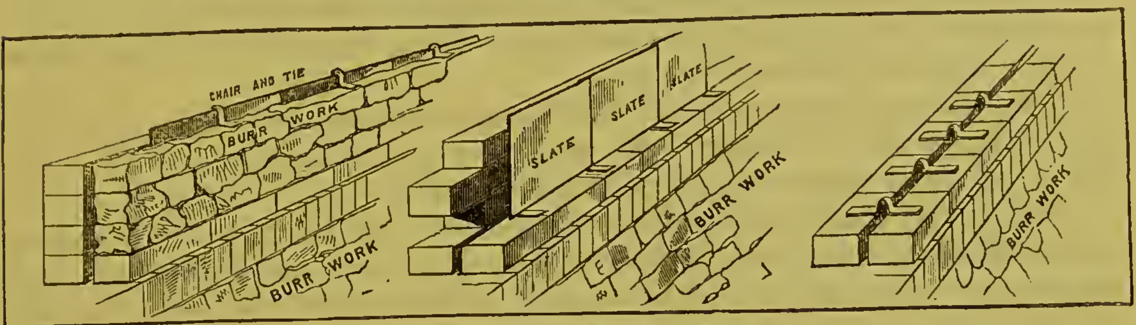


Fig. 12.—Slates in Damp-proof Walls.

the same object of preventing water from being conducted towards the inner portion of the wall. Where this kind of construction is resorted to, it is necessary to lay a piece of thin sheet lead over the heads of the door-frames and window-frames in order to protect them from being injured by any water that may get into the cavity. It is likewise very desirable to provide ample means of ventilation in the cavity.

In some exposed situations the external walls of buildings have been constructed with a narrow cavity which has been filled in, as the work proceeded, with asphalte,* or slab slate with iron cramps, so as to form a sort of vertical damp-course. Mr. John Taylor, in some houses erected from his designs in the Isle of Thanet, found that the ordinary hollow wall with iron ties was an insufficient protection against the driving rain and spray from the sea. The method he adopted was to build in a layer of ordinary roofing slates between two half-brick walls, Fig. 12. The cavity between these two skins of brickwork is just of sufficient width to allow the slates to overlap each other, and so present no interstices through which wet might penetrate. Each slate is supported on a piece of copper bent to form a "chair," and which also serves the purpose of a tie to connect the inner and outer brickwork.

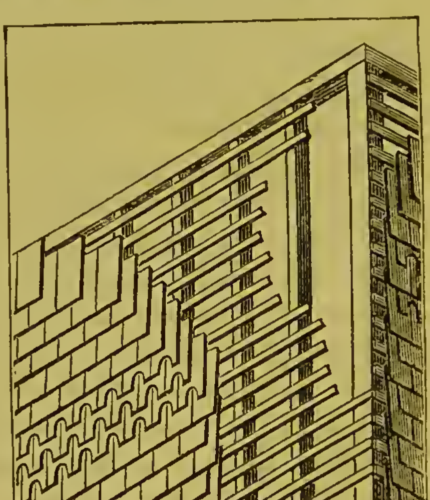


Fig. 13.—Tiled Frame Wall.

One other mode of forming hollow walls, which is prevalent in Surrey, Sussex, and Kent, is shown in Fig. 13. A framework is formed of *timbers*, the external face of which is covered with laths and tiles. The upper part of each tile, where it is hidden by the overlapping of the tile above it, is pointed with lime and hair mortar, to prevent the rattling that would otherwise be caused by the wind. The inner face of the framework is covered with ordinary lath and plaster work. A similar

* Infirmary at the Eastry Union Workhouse, T. E. Knightley, architect.

method of construction, in which slabs of concrete are substituted for the tiles, is likewise sometimes adopted. These modes of construction are obviously cheap and effective. The former is adopted for the upper storeys in many classes of buildings, from the barn or the cottage to the country mansion. Owing, however, to the extreme combustibility of these kinds of walls, they cannot be regarded as safe substitutes for ordinary brickwork, unless, by dispensing with the cavity altogether, the insterstices between the timber framing be filled in with brickwork, and a backing of brickwork at least four and a half inches thick, be placed on the inner side of the wall behind the timber framing.

The means of preventing the evils of damp in new houses have thus been fully described. In a future chapter, brief mention will be made of the remedies to be adopted in the case of old houses which suffer from the evil.

Thickness of Walls.—The thickness for the walls of a house is a matter of no slight importance. Adequate thickness is necessary alike for securing due stability, for keeping out the weather, and for protecting the interior of the house from the effect of changes in the external temperature.

Walls of houses are constructed of brickwork, stonework, rubble-work, or flint and boulder work. Sometimes a combination of these materials is used, such as brickwork with stone dressings, stonework with brick backing, flintwork with brickwork in piers and quoins, &c. Of late years, since the manufacture of good cement has been extended and cheapened, walls formed of concrete have come into use. Walls formed of a combination of brickwork and timber, known as half-timber work, have likewise recently been much used in consequence of the revival of the picturesque English domestic architecture, and the architecture of the period of Queen Anne. There are a few other kinds of wall-construction in use in certain districts. Thus in the eastern counties it is not uncommon to find the walls of small houses formed of "clay lumps," and in other parts what is known as "wattle and dab" walls are met with among the poorer cottages. But owing to the increased facilities for the conveyance of building materials that now exist almost everywhere, bricks are more generally adopted for building purposes than any other material. Even in some districts where building-stone is found on the spot, bricks are brought by railway for use in internal walls and otherwise. This is partly due to their being obtainable at very moderate cost, but mainly perhaps because of the great facility with which they can be used in the construction of a wall.

Bricks are ordinarily of a uniform size of nine inches in length by four and a half inches in width, and three inches in thickness. There is but little variation from this size throughout the country. In Yorkshire and Lancashire they are a trifle larger, while in the south they are often a little less in size. But for all practical purposes the dimensions above described may be referred to as the ordinary size of a brick; and experience has shown that it is the most generally convenient size both for the construction of walls, and for the bricklayer to handle when at work.

Under these circumstances it is not surprising to find that rules for the thickness of walls of houses are generally based primarily on the supposition that they are to be constructed of brickwork, and whatever different thickness may be necessary in the case of walls built of other materials, it can be prescribed merely by a specific deviation from the thickness that would be requisite for a brick wall.

This is the plan that has been adopted in the Metropolitan Building Act, and also in most of the local building acts and regulations throughout the country.

So far as stability alone is concerned, it will ordinarily suffice for walls built of any of the materials above mentioned to be formed of the thickness that is found necessary for brick walls, with the exception that in certain rubble-work walls, with what are known as random courses, or in which the beds of the stones are not laid horizontally, and also in walls of flintwork construction, a rather greater thickness is needed. An increase of at least one-third is generally requisite.

The quality of the materials that are used in the construction of the walls of a house will often necessitate a greater thickness than is absolutely required merely for purposes of stability. Thus it rarely happens that single-brick walls (nine inches thick) will effectually keep out the weather; and frequently a brick-and-a-half wall (fourteen inches thick) is inadequate for the purpose. In the same way, many kinds of building-stone are readily penetrated by a driving

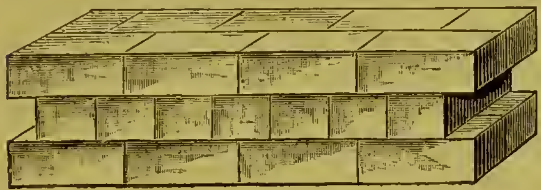


Fig. 14.—English Bond.

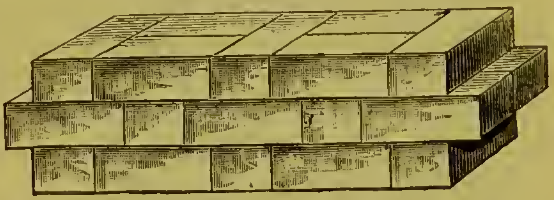


Fig. 15.—Flemish Bond.

rain. Hence an increase of thickness becomes necessary, or some of the precautions already described have to be resorted to.

In the construction of brick walls it is necessary to so interlace the bricks that they will tie the wall together in all directions. This is called "bonding," and it is necessary to take special notice of this subject, because in many houses, as ordinarily built, broken bricks, or *bats,* as they are termed, are often used instead of whole bricks, and the stability of the wall is thereby rendered less secure.

There are two methods of bonding in common use—one termed English bond and the other Flemish bond. The English bond (Fig. 14) is that in which the courses of bricks are laid alternately all lengthways, or "stretchers," and all endways, or "headers." In the Flemish bond (Fig. 15), which, as its name implies, was introduced from Holland about the time of William and Mary, the courses of bricks are laid with "headers" and "stretchers" alternating in every course. The English bond is held to be preferable, on account of its superior strength, as Flemish bond does not effect such secure tie, both lengthways and widthways in the wall, as the English bond.

Hoop-iron Bond.—It is not uncommon to increase the strength of walls by the introduction of bond timber or hoop-iron bond. Formerly bond timber was largely used in walls, but owing to its liability to rot, or, in the case of a fire occurring, to be burnt, and impair the stability of the wall, it has been almost entirely superseded by hoop-iron bond.

Whenever the foundations are at all doubtful, or where permanent security is specially needed, the use of hoop-iron bond in the walls is most valuable. It

consists of strips of hoop-iron, usually tarred to preserve it from rust, and sanded to assist the mortar to adhere to it, and is laid between the courses of bricks for two, three, or four courses in height, at the most convenient places in the elevation of the wall. One strip of hoop-iron should be laid in each half brick of the thickness of the wall. It is often deemed necessary to form these bonding tiers in cement brickwork, in order to secure an increase of strength of the entire tier. A patented hoop-iron bond is sometimes used, with the object of securing a firmer hold on the brickwork; it consists of strips of hoop-iron, with notches formed at distances of about twelve inches apart alternately along each edge, the corner of iron at each notch being turned up so as to effect a better key in the mortar or cement.

Stone walls for houses are more often built merely with a facing of stone and a backing of brickwork. Even in districts where stone abounds it is not unusual to adopt this mode of construction. The same may to a great extent be said of rubble walls.

Flintwork Walls.—Flintwork is used more for the smaller class of houses, inasmuch as it is inexpedient to build walls of this construction to any considerable height. These walls are composed mainly of mortar, and hence they have to be proceeded with comparatively slowly, in order that the mortar may have time to set and become hard, otherwise there would be risk of the weight of the upper part of the work crushing the lower part, and resulting in the collapse of the whole. There are many instances on record of the complete failure of new buildings erected with walls of this kind of construction during a continuance of wet weather, which has prevented the mortar from setting. Houses built of flintwork should always have in their walls a proportion of brickwork equal at the least to one-fifth of their entire bulk, properly distributed in piers and horizontal courses.

Concrete Walls.—Concrete walls have in recent years been much adopted, and when properly constructed with good materials are found to answer admirably, even for houses of considerable height. The concrete for this purpose ought to be formed of cement in preference to ordinary lime, as cement not only sets more rapidly, and thus obviates the difficulty just referred to in regard to walls formed of flintwork, but it is harder when it has set, and consequently insures a more secure construction, which is especially important in the case of buildings of great height. Concrete walls, if built of good materials, are often far more effectual for keeping out the weather than ordinary brick walls of the same thickness, and as they are somewhat cheaper to construct it is probable that they will become more commonly adopted than hitherto. They require special apparatus in their construction, and this has no doubt tended to retard their introduction.

In building a house of concrete the walls are formed by fixing a frame or mould of planks or iron plates, and filling it with the concrete, taking care to pack it well and ram it down. The concrete is put in in layers about six inches thick, until it reaches the top of the frame or mould. The concrete takes about a couple of days to set sufficiently hard, and the frame is then removed and refixed higher up, to allow of another course being formed, the courses being about eighteen inches in height. The two sides of the frame or mould have to be tied together by pins or bolts to keep them parallel, and the bolts are drawn out each time the frame has to be raised.

Special frames have to be used for angles of buildings, and moulds are required for forming the flues. It is convenient, moreover, to build in the frames of doors and windows as the work proceeds. The external face of the wall is generally finished with stucco, and decorated according to fancy.

Half-timber Walls.—Half-timber work has long been used in the domestic architecture of England. It is met with in various parts of the country, and numerous old towns possess specimens which are cherished with much fervour. There are some good specimens at Exeter, and even London, with all its modern reconstruction, is still not without some specimens of old timber buildings. The city of Chester, however, can show finer examples of this picturesque style than any other town in the kingdom. "The Rows" in that city are unique, and form one of the most interesting features for the curiosity of the visitor.

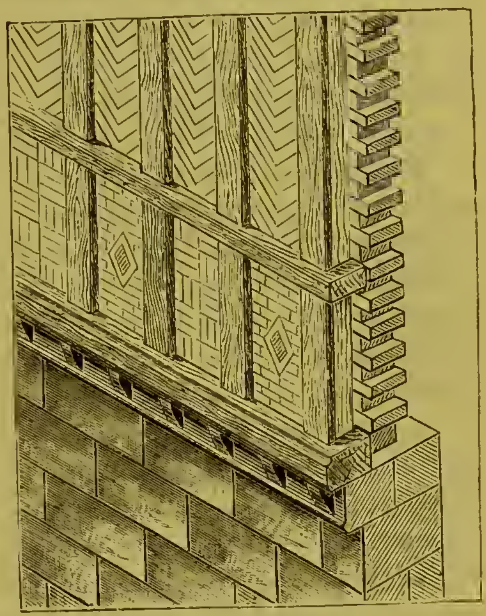


Fig. 16.—Half-timber Wall.

Of course, with the introduction of timber into the walls of a house, there may be a corresponding danger of fire; but this objection can be reduced to a minimum without much difficulty. The kind of construction in question is obviously not adapted for any but external walls, nor indeed, seeing that it is only for appearance that it would be used, would it be required for other than external walls.

For preventing the spread of fire it is necessary, in the case of attached houses, to avoid all continuity of the timber framing from one house to the next adjacent house. This is easily effected by bringing the party walls through to the front for their full thickness, and making them project a trifle beyond the face of the timber framing. For the rest it is very desirable that the interstices between the framing should be completely filled in with solid brickwork, and that there should be a four-and-a-half-inch thickness of brickwork at the back of the timbers, as described for tile-faced timber-framed walls. If these precautions are taken, there will practically be no risk of fire on account of this mode of construction.

Terra cotta is a material which has been extensively used of late years for building. It is made with certain kinds of clay usually mixed with other substances, chiefly glass, pottery, and sand, and ground up, strained, kneaded, and finally forced into moulds and baked in a kiln. The great difficulty to be contended with in the manufacture of terra cotta is the unequal shrinkage of the clay. Great care has to be exercised both in the preparation of the material and in the burning. On account of the richness and variety of its colour and the delicacy and variety of ornamental treatment of which it is susceptible, it is a valuable material. Its durability under the conditions of such an atmosphere as London has yet to be established. In point of cost it is probably about the same as Portland stone. Possibly, in very large works, where ornamental features are often repeated, the cost may be somewhat less. Examples of the use of terra cotta in important

buildings are to be seen in the new Natural History Museum and the Science Schools, both at South Kensington.

Before quitting the subject of the walls of a house it will probably be useful to refer to party-walls, and the precautions that are necessary for the prevention of the spread of fire from a burning house to the next house. It is to be remembered that Parliament, by giving to borough councils, local boards, and other sanitary authorities, power to regulate the proper construction of the walls of new buildings for the prevention of fires,* has imposed upon them a very considerable responsibility, and one which ought in no way to be neglected. Few persons who have not had the misfortune to occupy a house next to one that has been destroyed by fire can realise the feeling of distrust that rises up in the mind as to the efficiency of the protection afforded by the ordinary party-wall, and the chance that, owing to some improper construction, the misfortune that has befallen a neighbour may, in the course of a short half-hour, make similar havoc with his own house and property.

Of course, if every building were enclosed exclusively in its own walls, those walls would all be what are known as "external walls," and safety from the spread of fire by this channel would be almost absolute. But inasmuch as it would be a somewhat unnecessary expense, and consequently would act oppressively to require, in the case of attached houses, the adjacent external walls to be in duplicate, it is invariably permitted to substitute a single wall as the separation between attached houses, and it is this wall that is designated a "party-wall."

A party-wall has been defined as a wall used, or constructed to be used, in any part of its height or length for the separation of adjoining buildings belonging to different owners, or occupied, constructed, or adapted to be occupied by different persons. A party-wall is also a wall which, forming part of a building, stands, in any part of its length, to a greater extent than the projection of its footings on one side, on the lands of different owners.

A good party-wall is most important for the proper separation of all attached houses. It is the custom of most fire insurance offices to impose an extra rate of premium on any house that is separated from its neighbour by an imperfect party-wall, or by a party-wall which is not carried up through and above the roof. Even detached houses, if very near to their neighbours, may be seriously endangered if one of them happens to be destroyed by fire, for the flames may easily extend to the overhanging eaves or the rafters of the roof of a neighbouring house, if it be not sufficiently remote.

In order to obviate this danger, it is commonly prescribed in building Acts, and other building regulations, that in the case of any house being within a distance of fifteen feet from any other house the external walls on the side adjacent to the next house shall be carried up above the roof, so as to form a parapet at least twelve inches high.

In the case of attached houses, it is usual to carry up the party-walls through and above the roof, so as to form a parapet at least fifteen inches in height. This is necessary, inasmuch as, should one of the houses be destroyed by fire, the flames from it would be liable to be driven over the roof of the adjoining house, and the heat would quickly crack the slates and expose the rafters and other roof timbers, which would at once be ignited, and thus lead to the destruction of a second house.

* *Vide* 38 & 39 Vic., cap. 55, § 157 (2).

It is, however, obvious that these contingencies are more likely to occur in large houses and buildings filled with combustible materials, which, when on fire, would make a great blaze, than in small houses, and consequently this requirement is not infrequently applied exclusively to domestic buildings exceeding a certain specified height, and to warehouse buildings and public buildings; and in this way the additional cost that is incurred by the precaution is obviated in the case of small houses and labourers' cottages, where every extra shilling of outlay has to be avoided as far as possible. On the other hand, in the case of large buildings filled with combustible goods, which would make a great fire if they became ignited, a higher parapet than the one above described would be necessary if due security is to be insured, and three feet is frequently prescribed in these cases.

Wherever a parapet is formed it is important to take precautions against the possibility of damp soaking down the wall. This may be effected in various ways, and with various degrees of success. The parapet may be finished with a course of bricks on edge, laid in cement, with some plain tiles projecting below them, in order to prevent water from trickling down the sides; and sometimes what is called water-tabling is adopted, which consists of properly-sloped slabs of stone laid on the top of the parapet, and projecting a few inches over the sides. The parapet is occasionally cemented all over. An important point, however, in regard to the parapet, is the way in which the roof is finished against it, so as to prevent wet from finding its way into the building at that point. This is effected sometimes by what is known as a cement flashing, which is a pad of cement laid along the angle formed by the slates and the parapet. This kind of flashing, however, is never adopted in good work, because the slates are very apt to sink away from the cement, or to draw it away from the wall. The cement is then liable to crack, and become displaced, and thus to let the wet get into the building. A far better plan is to use lead flashing. The lead is inserted in the joints of the brickwork, and, covering the joint or angle formed by the slates with the parapet, extends on to the slates a sufficient distance to prevent the wet getting under them. Another method of preventing wet from soaking down the wall is to continue the slates through the wall, beneath the parapet, bedding them in cement, so as to form a kind of damp-proof course near the top similar to the damp-proof course that has already been described near the bottom of the wall.

Another subject intimately connected with the walls of a house, and which needs most careful attention in regard to the safety of buildings from fire, is the construction of fireplaces and chimneys, and the proximity of timber and wood-work to the inside of flues. The defective construction of flues, and carelessness in fixing woodwork, are among the commonest causes of damage to buildings by fire. The heedless way in which workmen sometimes drive wooden plugs and insert wooden bricks (for fixing door-frames, skirtings, &c.) in walls and chimney-breasts, so as even to project into a chimney flue, renders it a matter for surprise that fires from this cause are not of more frequent occurrence. It is not improbable, however, that many of the fires that are reported as of unknown cause actually owe their origin to defective construction of flues, or to woodwork being improperly fixed near them.

Chimney-flues are usually surrounded by brickwork, often not more than four and a half inches thick, and in order to form a smooth surface that will not

facilitate the adhesion and accumulation of soot, as well as in order to fill up all accidental interstices in the brickwork, the internal surface of the flue has to be covered with a kind of plaster known as "pargetting," and formed of lime and cowdung. Sometimes the flue is lined with stoneware pipes instead of being pargetted. In pargetted flues it is not at all uncommon, though most improper, to find that after the bricklayer has finished his part of the work, the carpenter drives wooden plugs in the joints of the brickwork in order to enable him to fix a door-frame or skirting round a room. In driving the wood plugs into the four-and-a-half-inch brickwork around the flue, he can scarcely avoid displacing a considerable portion of the pargetting in the flue, and thus the woodwork is exposed to the direct action of the heat in the flue; and if an accumulation of soot should occur near the wood and become ignited, there would obviously be very considerable danger of fire extending to the rest of the house.

In the same way, though perhaps with slightly less risk, timber is sometimes placed against the brickwork of a chimney-flue when it is of insufficient thickness. If the brickwork is only four and a half inches thick, there can be no perfect bond, and consequently there is risk of the joints being imperfect and of fire being carried through them by a draught to the timber in the immediate neighbourhood. Hence it is usual in such cases to require the outer face of the brickwork about a chimney flue, when it is no more than four and a half inches in thickness, to be plastered where any timber is near it.

It is necessary, where complete safety from fire is desired, to require the brickwork about a chimney to be at least nine inches thick, instead of only four and a half inches, at any rate up to a certain height above the fireplace, and this is specially necessary in the case of chimney-flues from kitcheners and scullery or wash-house copper furnaces, where the heat passing up the chimney is very great. Owing to the fact that kitchens are now so commonly fitted with close ranges, in which all the air that goes up the chimney passes through the fire itself, it is usual, in properly-constructed buildings, to surround the kitchen chimney with nine-inch brickwork for a height of ten feet or more above the top of the fireplace, and thus carry it safely past the timbers of the floor immediately above or of the roof.

CHAPTER III.

BRICKS, STONES, AND MORTAR.

Bricks—Mortar—Joints—Qualities of Stone—Failure of Stone used in the Houses of Parliament, and the Reasons—Laying Stones in their Natural Positions—Various Kinds of Stone used in Building—Slates and Tile-stones.

It will be useful here to refer to the quality of bricks and ordinary mortar, and the building-stones that are commonly used in the construction of the walls of houses. This is a point that is often lost sight of in the construction of the houses of the middle and lower classes, where the builder's chief interest lies in completing the house in the most expeditious manner, and at the least cost to himself, so that he may obtain an early purchaser and be relieved of all future responsibility. It is unfortunate perhaps that new houses so frequently find ready purchasers, for this is certainly an inducement to speculating builders to adopt inferior materials and imperfect work, where, either from its being speedily covered up, or from a want of technical knowledge on the part of the intending purchaser, it is not readily observed until some time after completion. Hence it is not uncommon in modern suburban villas and cottages to find that bricks of an inferior kind have been used for the walls, stone of a perishable nature for the sills and lintels, and that the mortar with which the bricks and stones are put together is little better than mud.

In the selection of bricks it must be remembered that those of uniform colour are generally picked out for facings, and therefore command a higher price. Those bricks which are heaviest and hardest are generally the most durable and best. One of the commonest methods of testing the quality of bricks is to take one in each hand, and knock them together. Bricks of good quality so tested will give a clear ringing sound. A good stock brick should weigh not less than about five pounds.

The ordinary red brick is generally more absorbent than the hard stock brick, and is therefore commonly used for dressings and ornament only, but red bricks of fairly dense and durable quality are nevertheless to be obtained. Some excellent machine-made white perforated bricks are frequently used for facings. The perforations lessen the weight, and so facilitate the carriage of the bricks, while they form a sort of key for the mortar, and also promote uniformity in the burning.

Mortar ought to be compounded of clean sharp sand and slaked lime ordinarily in the proportion of one part of lime to three parts of sand. Grouting, or fluid mortar, with which the interstices of the brickwork should be filled up about every fourth course, is merely ordinary mortar reduced to a liquid consistency by the addition of a greater quantity of water.

The sand that is used in mortar should be tolerably fine and free from shingle, or small stones. It is important, moreover, that it should be free from impurities, such as earthy or clayey matters, for it must be remembered that the ultimate strength of the mortar depends upon the adhesive quality of the lime and the particles of sand; and if the latter be coated with an intermediate layer of clay, the lime and the sand will easily be separated either by moisture or by uneven

pressure. Hence it is very desirable to wash all the sand that is to be used in a building so as to remove all clay or mud. Many builders are in the habit of using "road scrapings," but owing to the quantity of foreign matter it contains, including much that is capable of decomposition, its fitness is obviously not always to be relied upon. It is certain, however, that much inferior mortar is used in the erection of suburban villas and cottages, the walls being put together with only a scanty quantity of even that material, and the joints of the brickwork on the exposed faces are afterwards pointed with mortar of a somewhat better quality. Another feature in speculating builders' brickwork is the thickness of the joints between the bricks. This is a very common defect. The bricks, instead of having only sufficient mortar between them for the purposes of adhesion and of equally distributing the pressure, have a thick bed of inferior mortar, which readily absorbs a driving rain, and then, after a frost, soon crumbles away. The best joint for ordinary brickwork is a carefully trowel-struck narrow joint, never exceeding a quarter of an inch in thickness, and having the upper edge slightly indented, and the lower edge flush with the face of the bricks, or slightly projecting (Fig. 17, *a*). If good mortar be used, this joint will throw off the rain, and last for an almost indefinite time. Some joints in brickwork that are made by pointing after the wall has been built, such as "tuck" pointing (*b*), and "bastard tuck" pointing (*c*), seem specially intended to last only a few years.

The selection of stone for use in building is a point of the utmost importance, and no care or trouble should be spared to ensure that the choice made shall be that most likely to withstand the influences, whether natural or artificial, to which it may be subjected.

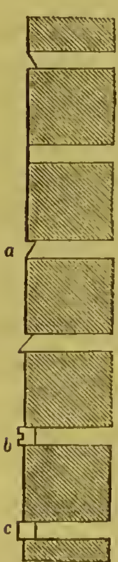


Fig 17.—Joints.

The use of stone in the smaller classes of houses is, except in localities where it is indigenous and cheaper than bricks, restricted to window-sills, steps, and ornamental appendages, commonly known as dressings. Where good stone is not readily at hand, and good bricks are to be had, the use of stone should be confined within the narrowest possible limits.

Most of the soft friable Bath stone, used commonly in small suburban houses to give an attractive appearance and thereby make them more readily saleable, will, long before the ground-leases have run their term, have to be replaced by other stone, as otherwise it will perish with the action of the weather, and disappear in an almost impalpable dust.

In selecting a stone for building, the first characteristic to be sought for is durability. Various methods can be adopted to ascertain if a stone possesses this property. The weathered face of the stone in an old quarry, or the exposed side of a cliff, is a valuable evidence of the wearing qualities of a stone where it is to be used in the immediate neighbourhood, or under similar conditions as to climate. Old buildings also afford valuable information as to the durability of the stone of which they are constructed. In these days of advanced geological knowledge, however, something more than tests of this sort, which are at best but superficial, is required. The chemical composition of a stone, taken in conjunction with the particular atmospheric or local influences to which it will have to be subjected,

should be carefully ascertained. In most large towns sulphuric and sulphurous acids, carbonic acid, and other deleterious gases, are absorbed by rain or the moisture contained in the atmosphere, and are thus brought into most intimate connection with the stone. Decomposition is the natural result when the stone used contains carbonate of lime or carbonate of magnesia to any large extent. The stone of which a considerable part of the Houses of Parliament is built is a magnesian limestone of an inferior kind. The smoke-laden atmosphere of London produces on its surface a soluble sulphate of magnesia (Epsom salts, in fact), which is washed down and disintegrated by successive rains and frosts.

Care must be taken to select the best stone that the particular locality or quarry will furnish. In every quarry there are many strata of varying qualities. The different degrees of durability can only be ascertained by actual experience; but it is important in any large undertaking to take steps to ensure the use of the particular stratum that may be selected. It was neglect in this particular which led to such lamentable failure at the Houses of Parliament.

As a rule it is desirable that all stone used in building should be laid on its natural bed; that is to say, that it should be laid as nearly as possible in the exact position in which it was originally deposited in the quarry. The reason for this is not far to seek. All limestones and sandstones belong to what are known as sedimentary rocks. The atoms of which they are composed were originally deposited at the bottoms of seas, lakes, or estuaries of varying depths and under varying conditions. They are, therefore, more or less laminated or stratified, and if the planes of stratification are placed at right angles to the beds of the masonry, there is a tendency to scale off by the action of rain and frost. It is necessary also to ascertain the original position of the stone, as it by no means follows that the plane of deposition is horizontal. Many rocks are tilted up at a very considerable angle by disturbances subsequent to the period of formation; the lines of lamination are, therefore, many degrees from horizontal. It is these lines of lamination which must form the horizontal bed of the stone, whatever be their present angle of inclination.

This rule is not applicable to granites or other metamorphic stone, nor to some of the more homogeneous kinds of sedimentary rocks, as, for instance, the millstone-grit, which can be laid in any position. It is also obvious that in the case of window mullions of great length the stone cannot always be laid on its natural bed.

The various tests by which the characteristic features of a stone may be ascertained cannot be minutely described here. It will be sufficient for our purpose to point out a few of the leading features for observation. "Speaking generally, in comparing stones of the same class, the least porous, most dense, and strongest, will be most durable in atmospheres which have no special tendency to attack the constituents of the stone."* The capacity for absorption and resistance to crushing are tests of some value, especially the former. Various other tests are available, but it is scarcely within the scope of the present work to enumerate them.

The uses to which stone is applied in domestic buildings may be divided into three classes: — 1. Purely ornamental purposes; 2. Constructive purposes; 3. Roofing.

For ornamental purposes, granite, and the numerous stones which are capable

* "Notes on Building Construction," Part III.

of receiving a high polish, and are classed under the comprehensive term of marbles, offer a vast field for selection for such purposes as chimney-pieces, paving, columns, and inlay. In point of colour there is scarcely any limit to the variety obtainable, from the pure white of the famous Carrara quarries to the black marble of Ireland and the beautiful greys and reds of the well-known Devonshire marbles. Very effective and not very expensive paving can be made from the chips from a marble mason's studio. An instance of this kind of paving, made by the female convicts at Woking Prison, may be seen at South Kensington Museum.

Granite has been largely used for ornamental purposes of late years, and, being susceptible of a high polish, and being also (with few exceptions) of a most durable nature, is of considerable value, both for its ornamental and constructive qualities. The great cost of working and also of transit must always tend to limit the use of granite to buildings of the larger kinds. It is, however, used in Aberdeen and other places in the immediate localities of the quarries very extensively as a building-stone. In Brittany also many of the old churches are built of granite, and the mouldings and tracery are as clear and perfect as the day they were cut.

As a cheap imitation of black marble, enamelled slate is frequently used for chimney-pieces and other purposes; very fair imitations of other marbles are also produced in this material at much lower cost than the real marbles.

The stone known as Serpentine, for indoor work, is scarcely to be equalled for variety and beauty of colour and figure. The well-known Connemara marble, or Irish Green, the red and mottled varieties of Lizard, and the "Verde antique" of the ancients, all belong to this class of stone.

The use of marble or granite, to any great extent, for architectural purposes, must of necessity, from its cost, be confined to the more expensive kinds of houses. Judiciously applied, however, a small quantity of polished granite or marble might advantageously take the place of the coarse and badly-executed stone-carving so much affected by the speculating builder.

For constructive purposes, stone is used in walls, floors, window-sills and heads, columns, steps, copings, and so forth. In places where good building-stone is indigenous, it is usually the most economical material for walls available; hence it will be found used for the humblest possible purposes, as pigsties and garden walls. In other places, where good bricks are available and are less costly than stone, the latter material will be found to be confined, except in cases where expense is not studied, to such uses as sills, copings, steps, dressings, &c.

The principal difficulty attending the use of stone as a material for the walls of a dwelling-house is that of keeping out the wet. As a protection from injury from this source, it is usual in many places (parts of Somersetshire and Devonshire, for instance) to build the walls of great thickness. Where stone is cheap there are great advantages accruing from this custom, one of which is that a house constructed in this manner is more likely to be cool in summer and warm in winter, approaching, in fact, to a uniform temperature.

In the neighbourhoods of large towns brick is the material most commonly used for the walls of houses, and the use of stone is confined to the accessories mentioned above. It is here that it becomes most necessary to exercise care and attention in the selection of the stone to be used, because it will be found that the positions in which stone is employed are precisely those most affected by the

weather. It is not an uncommon occurrence, for instance, to find the copings of garden walls of recently-erected houses, after a sharp frost, sealing off in large flakes. The cause is, of course, due to the freezing and subsequent thawing of the moisture contained in the stone; the stone itself being some soft friable freestone utterly unfit for outside work of any kind.

Of late years it has been much the fashion with speculating builders to use stone for bay windows and porches to houses of as low a rental as £30 a year. The one object being to attract purchasers by as showy an appearance as possible, no care is taken, nor indeed would the expense warrant care being taken, to select a durable stone. The consequence necessarily is that before the houses have been occupied many months, the stone begins to show signs of premature decay. Instances could be given of stonework of this description having to be coated with a protective solution before the house was completed.

For all ordinary purposes in London and the neighbourhood, Portland stone is undoubtedly the best-wearing stone to be had. It certainly stands the test of London smoke better than any other; evidences of this are to be found in St. Paul's Cathedral, and most, if not all the City churches, erected by Sir Christopher Wren after the Great Fire. The care which Wren exercised in selecting the blocks for actual use is evidenced to this day by the blocks discarded by him still lying in the quarry.

Bath stone is very considerably used for both exterior and interior work. It varies very greatly in quality, and much care should be exercised in its selection.

For landing-steps and paving, Yorkshire stone is extensively used. The finer and harder varieties make good and durable stone sinks.

Several other varieties of stone are available for use in building, as the red and grey Mansfield, Kentish Rag, Tisbury, and others. It will, however, usually be found that most kinds of stone can only be economically used in the neighbourhood of their respective quarries.

As regards the fire-resisting qualities of stone, it may be taken as a fact that limestone is more fireproof than sandstone. In an experiment made after the destruction by fire of old Doncaster Church, it was found that while a large block of sandstone flew to pieces after being placed in a fire but a short time, a similar block of limestone was only superficially calcined after twenty-four hours' exposure to the flames.*

Limestones also were recommended by the commissioners for selecting the stone for the Houses of Parliament, in preference to sandstones, "on account of their more general uniformity of tint, their comparatively homogeneous structure, and the facility and economy of their conversion to building purposes."

Of late years several kinds of artificial stone have been introduced, many of them of great beauty and fineness of texture. Their wearing qualities cannot, however, be spoken of with any certainty, while their great cost renders them at present unavailable for ordinary work.

The last class of stone to be mentioned comprises those used for roofing purposes. Under this head are to be found slates and tile-stones.

The ordinary slate used for roofing purposes is an altered form of clay of fine texture, originally deposited, in all probability, as a fine-grained silt, and subse-

* Beckett, "Book on Building."

quently subjected to enormous compression, which produced the laminated structure or "cleavage" which is a marked characteristic of this kind of rock. The special value of slate for roofing purposes is the ease with which it can be split along the planes.

The planes of cleavage are either at right angles to or parallel with the bed of the rock. In the former case the slate is used for roofing purposes, and in the latter as slabs for paving. The thicker bedded varieties are used for billiard and other tables, cisterns, chimney-pieces, baths, and other purposes where solid slabs are required. Slate slabs are comparatively of very considerable strength; "the strength of slate one inch thick is considered equal to that of Portland stone five inches thick."* Any size up to six or eight feet in length, and from one to three inches in thickness, can be readily obtained. Greater sizes than these are more costly in proportion. The slabs can be finished with a sawn face, or they can be planed, polished, or enamelled. The latter process consists of first painting, then baking, then painting again to the colour or pattern required, then covering with a coating of enamel; the slab is then baked and rubbed down several times alternately, and finally polished.

The Welsh slates are usually considered the best, and of these the best known come from Bangor and Penrhyn. The Penrhyn slate-quarry is half a mile in length and a quarter of a mile in width, and the slate is worked in large terraces, some thirteen in number, "like the steps of a Titanic stair." More than three thousand men are there employed in the making of slates, which are exported to all parts of the world.†

English slates are thicker and coarser than those from Wales. Good slates of a green tint are quarried in Cumberland; and durable slate slabs come from Delabole, in Cornwall.

Irish slates are of several qualities, the best being similar to the Welsh. Some writers consider them superior in toughness to Welsh slates.

Scotch slates are very durable, though coarse. They often contain a large proportion of iron pyrites, which does not seem to militate against their wearing qualities. The best Scotch slate comes from Ballachulish in Argyleshire.

Tile-stones are thin bedded sandstones, formerly largely used for roofing purposes. They are still used in some parts of the country (Devonshire, Gloucestershire, and Westmoreland), where they are cheaper than slate, and being much thicker than slates have the great advantage of protecting the interior of a house from excessive heat and cold. The principal drawback to their use is their great weight compared to that of ordinary slates.

* Papworth.

† Ramsay, "Physical Geology and Geography of Great Britain," 5th ed., p. 591.

CHAPTER IV.

ROOFS AND ROOFING.

Importance of a good Roof—Slope of a Roof—Slates, and their Sizes—Lap and Method of good Slating —Tiles—Lead and Zinc—Thatch—Access to the Roof—Spouts for Rain-water.

NOT the least important part of a house is the roof. A house with an imperfect roof is, as most householders know to their cost, a constant source of trouble and expense. Who does not dread being obliged to have workmen on the roof, from the firm conviction that they will damage as much as they go to repair. Roofs, like foundations, cannot readily be thoroughly examined by intending purchasers, and consequently they afford opportunity for neglectful work on the part of the speculating builder; and yet the comfort of a house very largely depends on the roof. It may fail to keep out the driving rain and snow, or it may allow such an accumulation of snow that on a thaw taking place the water is unable to get away as rapidly as it ought, and it consequently overflows the gutters. The roof may be so constructed, moreover, as to allow the interior of the house to be inconveniently affected by the temperature of the external atmosphere, and also by the noise of rain or hail. In fine, a house, to be thoroughly comfortable, must have not only good and wholesome foundations and substantial walls, but a thoroughly good roof. These three parts of a house—the foundations, the walls, and the roof—are obviously of the utmost importance in every way, and in each of them goodness of material and of workmanship is indispensable, if they are to answer their purpose efficiently and satisfactorily.

Roofs are generally covered with slates or tiles, but other materials are occasionally used. In many localities, where suitable stone is to be found, thin slabs are adopted. Zinc, lead, and even copper are also used under some circumstances; thatch is used in rural districts; and tarred felt for many temporary buildings.

The slope for a roof will depend upon the material with which it is intended to cover it. It will be readily perceived that a metal covering, in which the joints are specially formed and are comparatively few and far between, may be almost flat, needing only just sufficient inclination to cause the rain-water to flow away. Slab slates of large size may be laid with an inclination of about 22 degrees, while ordinary slating should have an inclination of not less than about 26 degrees. Stone slabs and tiles of various descriptions are more porous than slates, and do not allow water to run off so freely; they, therefore, need an inclination of about 30 degrees with the horizon, while thatch should have 45 degrees of inclination.

Slates, like other building materials, differ considerably in quality. The characteristics of a good roofing-slate are hardness, fineness of grain, and small capacity for absorption. A brittle slate will crack and scale off at the edges when it is squared, and will easily break with uneven pressure when in position on a roof. A soft slate will readily absorb moisture, the nail-holes will enlarge, and finally the slate, in all probability, drops off. A good slate, if immersed for a few hours in water up to half its length, should not show any signs of moisture above

the water-line. Another common test of a good slate is its smell. If it emits a clayey smell when moistened or breathed upon, it is said to be not capable of resisting the action of the weather. Implicit reliance, however, should not be placed on any one of these tests. The grain or texture of a slate is readily seen, and if the slate be of a fine and even texture, without streaks or veins, it may generally be regarded as of good quality. Slates with veins or dark streaks running in the direction of the length should be rejected, as the slate in that case is almost sure to split along the vein. A good slate should give a clear metallic ringing sound when struck.

The slates used for ordinary roofing purposes are cut in the quarries to various sizes, which are known technically as "Empresses" (26 by 15 inches), "Princesses" (24 by 14 inches), "Duchesses" (24 by 12 inches), "Marchionesses" (22 by 11 or 12 inches), "Countesses" (20 by 10 inches), "Viscountesses" (18 by 9 or 10 inches), "Ladies" (varying from 16 by 10 inches to 14 by 7 inches), "Doubles" and "Smalls" (about 12 by 6 inches). There are also some slates of large size known as "Imperials," "Rags," and "Queens," but these, which have a surface of from five to six square feet, are not often used.

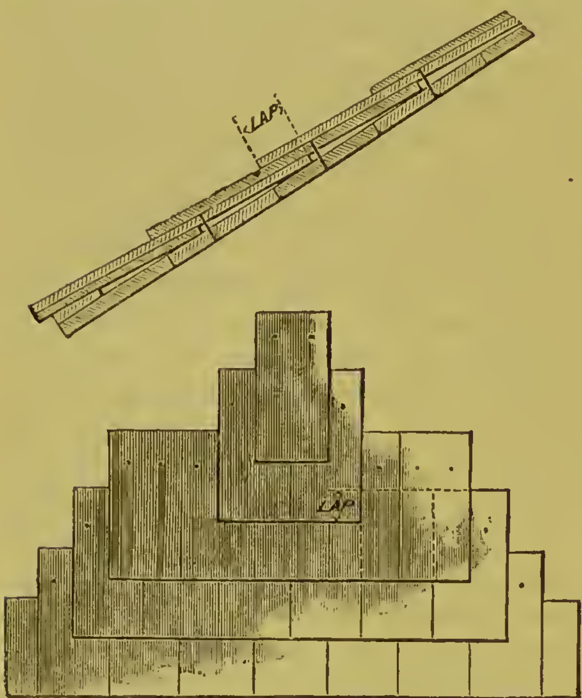


Fig. 18.—Lap in Slate Roof.

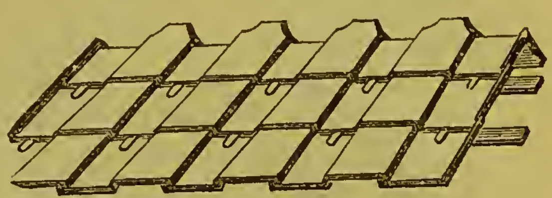
The size most generally used is "Countess." The thickness of a good Countess slate is about one-sixth of an inch.

Good slating should be laid with a three-inch lap, that is, each row of slates should overlap the head or upper part of the second row below it by three inches (Fig. 18). This is a very important point in slating a roof, for if, as is sometimes the case, the lap be only about one and a half or two inches, a strong wind will drive the rain or snow under the slating. The slates ought to be laid on boarding, and if it be desired to protect the interior of the house from the effects of heat and cold on the roof, it is useful to interpose a layer of felt between the boarding and the slates. Where expense is an object, laths are substituted for the boarding; but this is not a very judicious method of forming the roof, as the laths do not afford such a uniform support for the slates, and consequently the slates are more liable to damage by any one having to go on the roof. Slate laths, moreover, do not preserve an even temperature within the building as is the case with boarding, nor do they in any degree deaden the sound of heavy rain and hail. When laths are used it is necessary to point the under side of the slates with hair mortar—a process technically termed "torching"—in order to prevent the wind blowing through the joints and causing the slates to rattle, and carrying with it rain and snow. Slates are fixed in their places with nails of copper or zinc. Sometimes nails of a composition

of copper and tin are used, and in very inferior work iron nails are used. Copper nails are the best, but zinc and composition nails answer all ordinary purposes, and are much less costly. The ridges and hips of slate roofs are covered with slate slabs screwed to the boarding, and a slate roll fixed along the joint, the whole being put together with putty or white lead. Sometimes, for good work, lead ridges and hips are used, and where expense is an object, tile ridging is adopted. Red tile ridging has been used with good effect on green slating. It requires care in manufacture, and the joints are pointed with cement coloured with red brick-dust.

The valleys and gutters may be formed of lead, or in cheap work of zinc. Lead or zinc is also used for the flashings, which, as previously described, are fixed at the angles formed by the slating with the brickwork, in order to prevent the wet getting in there. Cement is likewise used for this purpose, but is a very indifferent substitute for lead.

Tiles are formed of baked clay-earth, and those ordinarily used for roofing are known as plain tiles and pan tiles. The former are flat, and measure about ten and a half inches by six and a quarter inches, and are rather more than half an inch thick. They have two holes in them for oak pins, with which they are fastened to the laths. Pan-tiles are of Dutch introduction, and measure about fourteen and a half inches by ten and a half inches. They are of a bent form, having transversely both a convex and a concave surface, so as to overlap each other laterally. They are hung on the laths by a projecting knob at the back. Other tiles of more or less ornamental character are occasionally used, such as flat Italian tiles, having raised edges along the sides to receive a covering row, or a row of covering tiles, and along the top, to prevent rain from being driven up under them (Fig. 19). Corrugated tiles are likewise now frequently used.



No. 19.—Patent Roofing Tiles.

Metal covering is chiefly used for flat roofs. Lead, from its durability, as well as from the facility with which it can be worked, is probably the most suitable material for the purpose, but it is heavy, and involves considerable strength in the timbers upon which it is carried. Copper is so rarely adopted in this country that its use need scarcely be described. Zinc, in recent years, has been largely used, both as a covering material and for ornamental work. It is much lighter and cheaper than lead, and its manufacture has of late, as is alleged, been so far improved that its durability is greatly increased. Both lead and zinc are laid in widths, with the edges dressed over a wooden roll. The circular rolls in Figs. *a* and *c* (Fig. 20) are best adapted to lead-work, and the angular roll in Fig. *b* to zinc-work. This method has to be adopted in preference to fixing with solder or nails, in order that the metal may have a little space to expand and contract in, and also because nails have to be avoided as far as possible, on account of the galvanic action that would result in the destruction of both materials. Lead for roofing

Fig. 20.—Lead and Zinc Joints.

should be what is called milled—that is, rolled out into sheets—and where it is likely to have much walking on it, it should be of a substance known as six pounds or seven pounds to the foot superficial. For places where there is no traffic five pounds to the foot, or even four pounds will suffice. It measures about ·017 of an inch in thickness to the pound weight per foot superficial.

Zinc, such as is ordinarily used for roofing, weighs from nineteen ounces to twenty-six ounces to the superficial foot. It is most important that zinc, when used for roofs, should be very carefully laid, and instructions on the subject are issued by the principal zinc manufacturers for the guidance of builders.

Thatch makes a most comfortable roof. It protects the interior of the house from extremes of warmth and cold, and is far more picturesque than slates, but for sanitary reasons, elsewhere referred to, it is not to be commended. It is, however, rapidly giving place to other materials, mainly on account of its being comparatively much less durable, and subject to injury by birds; and also because of the greater danger of fire, for in dry weather it would be easily ignited by sparks from a chimney. It is usually about fourteen or sixteen inches thick, and will last from fifteen to twenty-five years. It lends itself readily to all kinds of irregularities in the roof, and hence dormer windows are easily formed in thatched roofs, and add to the picturesqueness of this mode of construction. Sometimes cottages are met with in rural districts

THATCHED COTTAGE AT TISBURY.

that have an almost grotesque appearance, owing to the manner in which the dormers are found in the thatch. In the annexed illustrations of two old cottages at Tisbury in Wiltshire one can almost trace the features of grotesque faces.

Wherever practicable, some arrangement should be made for affording access to the roof of the house from within. There is much objection to providing no other means of access to the roof of a two-storey or three-storey house than by a ladder

THATCHED COTTAGE AT TISBURY.

placed against the eaves or the parapet. A long ladder, at best, is an inconvenient thing to place against the roof, and may inflict damage on the eaves; while it is not always easy to procure one when wanted. Access to the roof should be by a dormer, with a step-ladder leading thereto, and fixed in its place, so as always to be available when wanted. Trap-doors following the slope of the roof are always inconvenient, and very frequently let in rain. In lofty and high-pitched roofs iron

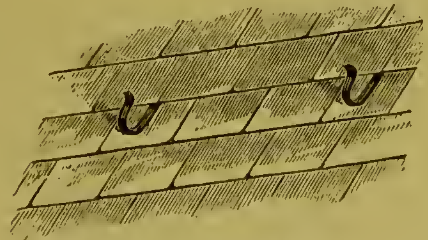


Fig. 21.—Hooks in Roof.

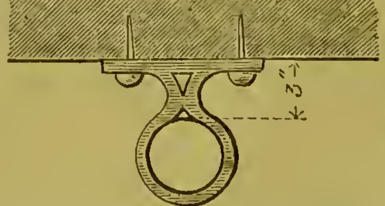


Fig. 22.—Section of Rain-water Pipe, showing it fixed three inches from Wall.

hooks may with advantage be fixed at intervals, as in Fig. 21, on which to secure the ladders used in repairing the slating or tiling.

The down spouts, for carrying away rain-water from the roofs, should be fixed two or three inches away from the wall (Fig. 22), in order that, in the event of their becoming stopped and overflowing, the water may not run down and soak into the wall.

CHAPTER V.

ARRANGEMENT AND PLANNING.

Difficulties in planning Small Houses—Cottages—Small Suburban Houses—Their Common Deficiencies —The Small Semi-detached Villa—Large Houses—Essentials in planning Houses of any Class.

"Houses," says Lord Bacon, "are built to live in, not to look on; therefore let use be preferred before uniformity, except where both may be had." The fundamental principles of house-planning could hardly be more succinctly stated. The primary objects to be attained in arranging the various parts of a house are the health and comfort of the inmates. These two considerations are, indeed, so intimately connected with each other that it may with justice be affirmed that a house in which the arrangements are in accord with the laws of health will also be a comfortable one to live in.

Upon the way in which the various rooms and appurtenances of a house are arranged depends very largely the comfort and health of the inmates; and this is true, not only of large mansions, but also, and perhaps even more so, of the smallest cottage. The more limited the space, the more necessary it becomes to utilise to the best possible advantage every available inch. It is, however, unfortunately, more the rule than the exception that in houses where space and outlay are confined within the narrowest possible limits, the skill and thought devoted to making the best possible use of both, are of the most meagre description. The long rows of small houses constantly springing up in the outskirts of our large commercial and manufacturing towns might almost have been made in some huge mould, so exactly is every fault both of construction and planning repeated with unerring regularity in house after house. The one idea that is prominent, the one thought that pervades the whole, is how to build houses sufficiently attractive to sell, without regard to durability, to comfort, or to health. The result of such a system is, as might be expected, a dismal uniformity, a persistent repetition *ad nauseam* of a design which, if it were as good as it is, as a rule, bad, would become intensely monotonous if repeated without break or relief throughout both sides of an ordinary street.

In the most elementary type of house, the country labourer's cottage, the planning is a matter of extreme simplicity; a living-room, a kitchen and a wash-house on the ground floor, and three bedrooms above, together with some small recess or closet for larder, and a fuel-store and earth-closet in the garden, comprise the whole of the needful accommodation; and to arrange these in a manner consistent with convenience, decency, and health, is no very difficult matter. The area and height of the various rooms will of necessity be small; all the more necessary is it therefore to so dispose the several parts that the greatest possible use is made of the space. A cupboard contrived under a staircase, fireplaces ingeniously dovetailed into each other, and perhaps a projecting window judiciously placed, add immeasurably to the comfort of the inmates without increasing the cost. The common fashion of entering the staircase only from one of the living-rooms is not to be commended; it is always possible so to arrange that the staircase is

approached from some kind of lobby, however small. Neither is it necessary to plan the staircase in such a way that ascending it becomes almost a climbing feat. It ought surely to be considered that people who inhabit cottages are as liable to old age and infirmities as their more-favoured fellow-people, and for this reason, if for no other, a cottage staircase should be made fairly easy of ascent.

A good roomy porch with a seat or two is a most desirable adjunct to a country cottage, and care should always be taken to place it on the warmest side, by preference towards the west. Such an addition will always be thoroughly appreciated by the inmates.

A common fault in many country cottages is the absurdly small size of the windows, originally due, in all probability, to the imposition of the window tax, relics of which may frequently be seen to this day in blocked-up windows; the same narrow dimensions are still preserved as if the tax were still in force, and glass were still as expensive as of yore. Good wide windows, with plenty of capacity of opening, are at least as necessary to the cottage as to the mansion; and the means of opening and closing them should be as simple and strong as possible.

Another familiar and picturesque feature of old country cottages is the large and roomy chimney-corner, or "ingle nook," in which there is frequently room for half a dozen people to sit by the fire with comfort. It has migrated from the labourer's cottage to the lord's mansion, where it is reproduced with all the luxurious appliances of carved oak settles, wrought brass and iron "andirons," and little stained-glass windows. The enormous mass of brickwork can no longer be economically applied to a cottage which is to be let at a rent of perhaps three shillings a week, and gives place to just the mere amount necessary to set a small range, and to carry the chimneys of the bed-rooms above.

It is advantageous for several reasons to build cottages in pairs; it is economical, as but one wall will serve to divide the two; one well, one rain-water tank, and often one bakehouse will suffice for both cottages. The chimneys also, by being all gathered into one central stack, will draw better than if built independently on an outside wall, and the heat from them will benefit the inmates of the cottages instead of being radiated into the outer air.

A useful and sometimes a necessary adjunct even to a small cottage is a larder of sufficient size to serve the double purpose of larder and dairy—this, as well as the wash-house, and perhaps the scullery, may be floored with bricks or tiles, but always on a substratum of concrete.

There are, of course, many varieties of cottages between the very smallest, which contain but four rooms, and the largest, but the foregoing remarks apply equally to all, the difference being chiefly in the matter of size.

There is no class of house which stands in so much need of improvement, both in planning and construction, as the small suburban six or eight-roomed house. While thoughtful and philanthropic landowners have for some years past spared no pains to render the homes of their labourers as healthy and attractive as possible; while, under the intelligent care of great manufacturers, towns like Saltaire and Akroydon have been built with every appliance possible for conducing to the moral and physical well-being of their workpeople, the dweller in the smaller kind of suburban villa, which is really but a step removed from a cottage, is entirely at

the mercy of the speculating builder. Compelled by the exigencies of his occupation to live within a certain radius of the scene of his daily work, and limited in his choice of locality by considerations of cost, the hard-worked city clerk has no option but to take what is provided for him; go where he will he finds but a repetition of the same thing dressed up in a different garb.

In the class of house now under consideration there is practically not very much scope for variation; it is on a minute attention to details often of a seemingly trivial kind that success in planning almost entirely depends; and it is the want of this attention, and the utter disregard of minutiæ, that causes the endless discomforts experienced by the unfortunate tenants.

The problem to be solved is briefly this: to arrange upon a parallelogram of land about 16 feet wide and about 100 feet deep, a house containing, say eight rooms, with the necessary adjuncts, so as to obtain the greatest possible space at the least possible cost. It is obvious that in certain points, as, for instance, the position of the front door and the staircase, there is no scope for variation. It is not, however, necessary that when the front door is shut the entrance passage should be wrapped in semi-darkness, nor that the staircase should be so tortuous, steep, and dark, as to render its ascent and descent a feat of difficulty and danger to young and old. In the question of aspect too, the builder is necessarily tied by the direction of the road; it does not, however, follow that the houses on the north side of a road running east and west, must or ought to be identical in every respect with those on the south side. Numberless instances could be adduced of the same plan being repeated on both sides of a street, with the result that on one side the kitchens, sculleries, and larders have monopolised the sunny side of the houses; a little thought and a departure from stereotyped precedents would have obviated such an absurd arrangement. A feature of some difficulty in planning houses of this small type is the best position for the water-closet. Ordinarily it is placed outside the house at the extreme rear, and this for purposes of drainage has considerable advantages. This arrangement has, however, the very serious disadvantage that the water-closet is approachable only through the open air. The best position on the whole is off the first landing of the staircase.

Perhaps the most serious defect in point of accommodation in these houses is the utter absence of all cupboard and storage room. Frequently two miserable little closets, one on either side of the fireplace in the sitting-room, and a few shallow shelves enclosed with a door, in the kitchen, are all that it is thought necessary to provide. Of course, large store-closets and linen-rooms are out of the question, indeed would be out of place, but some provision ought undoubtedly to be made, not only for the storage of a moderate quantity of provisions (groceries and the like) and linen, but also for boxes and the inevitable "lumber." In most cases a little additional strength in the ceiling joists of the top floor, a few rough floor-boards, and a step-ladder, would, at a very small additional cost, give the requisite storage-room for boxes.

The kitchen must of necessity be small; it should be as well lighted as circumstances will permit, and the common plan of entering the garden direct from the kitchen should, if possible, be avoided. Some sort of scullery, however small, must be provided, likewise a small larder. This last may be a mere cupboard in size, but must be ventilated into the outer air, and the ventilating opening must not be in

close proximity either to the water-closet or the dust-bin; both faults of every-day occurrence.

Coming now to a somewhat larger class of house, the semi-detached villa of a rental of from £50 to £65, it will be found that while there is very much more scope for variation in planning, the amount of thought and ingenuity usually bestowed on the arrangement is still at a minimum. The ordinary plan of a London suburban house of this class is as follows: In a half-sunk basement storey, the front room is a sitting-room or breakfast-room, and the back room is the kitchen. Under the steps leading to the front door is a small cupboard dignified by the name of larder, and the coal-cellar, whilst in the area immediately under the larder window is the dust-bin. The side of the house is occupied with the staircase and passage, into which, commanding a full view of the breakfast-room, the tradesman's entrance opens. Under the stairs is a dark closet, tenanted by a miscellaneous collection of rubbish and cockroaches. At the back of all is a small dark scullery, from the uncovered bell-trap of whose sink the foul air of the drain uninterruptedly ascends. Beyond this again is the servants' closet, the sole means of ventilation of which is the door; of means of lighting there are none. Ascending the stairs, on the ground floor will be found dining-room and drawing-room, probably with folding doors between, thus rendering them for all practical purposes one room, and a small third room. Above, on the first floor, are two bed-rooms and a dressing-room; on the second floor three bed-rooms, whilst off the half space will be found a bath-room and a water-closet.

The practical defects of this plan consist first in the arrangement and size of the sitting-rooms. The basement room is, as a rule, an inconvenient and often almost useless apartment, while the small room on the ground floor, right enough in point of position, is, in point of size, too small to be of any real use.

Again, the two principal sitting-rooms are not of sufficient size for one to be used independently of the other, and too large if thrown together into one. The remedy for all this is to do away entirely with the basement, put the kitchen and scullery on the ground floor, and increase the size of the sitting-rooms.

The house will cover more ground, but the increase in comfort and convenience, and the economy of labour effected by abolishing the basement and placing the kitchen on the same floor as the sitting-rooms, will usually more than compensate for the loss of space in the garden.

A good arrangement for such a house as is now being discussed would be as follows: On the ground floor a porch, placed, if the house be semi-detached, at the side, would give access to the entrance-hall. The porch should be so constructed that, without being necessarily very deep, it should afford shelter from driving rain. Frequently the height of the lintel is so great that the porch is literally no shelter whatever; this can easily be remedied by forming a glass screen of just sufficient height to afford clear headway, but low enough to afford protection from rain to persons waiting in the porch.

Inside the entrance on one side would be the dining-room, on the other the drawing-room and a small study; adjoining the dining room a small pantry and store-room might be arranged.

At the back, and approached by a passage which might be shut off by a door from the front part of the house, would be the kitchen with scullery, larder, and servants'

water-closet. Upstairs, on the first floor would be two bed-rooms and a dressing-room in the main portion of the house, and a small bed-room and linen-closet over the kitchen. On the second floor two large bed-rooms, divisible into three, if required, over the front portion of the house, and a bath-room over the back portion. Half way up the first flight of stairs would be the water-closet and housemaid's closet.

The success of such a house depends, however, mainly on the way in which apparently unimportant or minor details are worked out. By arranging two fireplaces together, by forming a recess, here for a sideboard, there for a perambulator, and by providing cupboards in sufficient number and of ample size, a small house may be made to yield as much accommodation and more comfort than a considerably larger one, the arrangement of which had not been as carefully studied.

No part of a house is worthy of more thought and care in designing than the staircase, and no time spent in working out the details will be thrown away. As an instance of how by a simple expedient the bed-rooms on the top floor of a small house may be very materially improved, the house at Telford Park, illustrated later on, may be cited. By starting the upper flight of stairs opposite the lower flight instead of returning them in the usual way, the back room is very greatly improved, and at the sacrifice of only a small part of the front room. Again, it is the almost invariable rule in suburban villas, small and large, to arrange the staircase so that it faces the front door. It will, however, frequently be found a far more convenient plan to place it the other way; it will be found to admit of the formation of a recess in which to stand a perambulator, or for hats and coats, and also of an inner lobby.

The position of the water-closets is often a matter of some difficulty, especially in the smaller classes of houses. It is well-nigh impossible to secure that amount of privacy which is desirable when, as is generally the case, the landing of the stairs is the only available place for the best water-closet. But it is neither necessary nor desirable to carry the soil-pipe down one corner of the drawing-room in such a manner that every time the contents of the basin are discharged the sound of water rushing down the pipe is distinctly audible in that apartment.

The servants' water-closet may, as a rule, be placed outside; the minor inconveniences of having at times to approach it through the rain is more than counterbalanced by the decided advantage of atmospheric connection between it and the kitchen being effectually cut off.

A pantry, however small, is an adjunct of the greatest value to a house. In the larger kinds of houses it may be enlarged so as to serve both for china and glass and as a store-room for the mistress of the house. Its place should be within a convenient distance of the dining-room, and always on the same floor. When the larger kinds of houses above the ordinary suburban villa type is reached, the pantry, of course, becomes a comparatively large apartment, and there will, moreover, be two in place of one; this arrangement will be described more in detail later on.

In details of construction the faults of the ordinary speculating builder's house are many and glaring. Thin walls built of soft perishable bricks, weak floors formed often of timbers bearing within them the seeds of decay, partitions of wood and plaster, designed apparently for the express purpose of conveying sound from

one room to another, are a few of the most salient errors prevalent in the average suburban villa. Perhaps the one of these most conducive to discomfort is the last. The thin uprights of wood cased over with lath and plaster which do duty as partitions afford scarcely more privacy than the paper walls of a Japanese house. It would be well if a rule existed, that where timber partitions are used the interstices should be filled in with some non-conducting material. A more serious defect is the almost invariable difficulty which, on account of the mode of construction usually adopted, is experienced in keeping the uppermost rooms warm in winter and cool in summer. The sole protection interposed between the rooms and the outer air is the ceiling and the slates. The formation of a box-room in the roof, as suggested above, would tend to improve matters, but no roof can be considered satisfactory that is not boarded and felted under the slates. It is all the more necessary to insist upon this, because it will frequently be found that the walls of the upper floor are only two-thirds of the thickness of the walls below.

The finishings of a house, cornices, door-furniture, bells and bell-pulls, mantel-pieces, stoves, gas-pipes, and so forth, all need care and judgment in selection. The cornices and centre flowers, so beloved of speculating builders, are generally heavy, tasteless, and inappropriate. A simple and well-designed cornice without "enrichments," and a few delicate mouldings running across the ceiling and dividing it up into panels, are far more effective means of decorating a ceiling and making it possible to obtain an harmonious effect between ceiling and walls than the ordinary methods. A further advantage is that with an arrangement of the kind suggested the gas-pipe can be made to form part of the ceiling decoration and be painted so as to appear to be part of the mouldings. The advantage of this over the common practice of burying the gas-pipe between the floor-boards and the ceiling is obvious.

To go into such matters as chimney-pieces and stoves would be trenching upon topics that will be dealt with hereafter; it may, however, not be amiss to point out here how very necessary it is that the greatest care should be exercised in the setting of stoves of all kinds. There is no more frequent cause of fires in dwelling-houses than the defective setting of a stove. An instance may be given which, had it occurred in an ordinary suburban villa, would have infallibly resulted in the destruction of the greater part of the premises. In a house in London, occupied entirely as offices, the occupants of the first and second floors were continually troubled with smoke, which appeared to come, not down the chimneys, but from every crevice and cranny in the old panelled walls. The nuisance grew worse, and in order to find out if possible the cause, the whole of the panelling on the second floor was removed, when it appeared that the smoke first became visible from a corner of the ceiling next the wall which carried the chimneys. On taking up the boards of the floor above, the joists were found to be blackened and slightly charred, and the cause of the evil was thus traced to the back of the grate. On this being taken out it was discovered that the back was quite hollow and open to the timbers. In course of time the thin back of the grate had been partly worn away, and finally, by the aid of the poker, actually pushed into the hollow space behind. Live coals followed, and the only thing that prevented the outbreak of fire was the fact that the floor was pugged with a solid mass of lime and hair, which had been so well prepared that it had set as hard as cement. The live coals fell, of course, on this pugging, and, in the absence of draught, burnt out without doing any further

damage than charring the joists and floor-boards, and flooding two storeys with smoke.

Hitherto the smaller classes of houses have alone been discussed. It is necessary to refer briefly to the various larger kinds of houses, but inasmuch as they are generally designed to suit special needs and special circumstances, and moreover have, as a rule, the advantage of professional skill and design in their conception and supervision in their erection, there is not, perhaps, the same necessity for pointing out prevalent errors in planning and construction.

The same general principles, nevertheless, apply to all houses alike, and no one who has had experience of house-building will fail to recognise the fact that no amount of altering, however skilful and ingenious, will compensate for grave errors of judgment in the original design of a house.

Dwelling-houses of a more extensive character include two distinct sets of apartments—the family rooms and the servants' rooms—and these again, in large mansions, are subdivided—the first class into visitors' rooms, family rooms, and the nursery suite; the second into male servants' and female servants' sets. The perfection of planning is to arrange all the various rooms required compactly, and, at the same time, to give the requisite isolation to each room and to each suite of rooms, and with the least possible expenditure of space in passages.

Formerly in England, and at the present day in many parts of the Continent, it was only considered necessary to provide a suite of rooms opening one into the other, with no external passage of communication. This arrangement no longer suits our ideas. We must have free and independent access to every room without passing through another, and doors leading from one room directly to another are the exception. The servants' part of the house must also be shut off from the reception-rooms, but this must be done with due regard to the distance between the dining-room and the kitchen. And in the servants' offices the same rule must be observed of not making one room a passage to another. Thus the butler must not have to pass through the kitchen in order to reach his pantry. Neither must the housemaid have to go through the butler's pantry to get to the china-closet. Again, convenience of service must be studied in the arrangement of such details as housemaid's closets and sinks, hot and cold water taps, coal-stores, water-closets, bath-rooms, and the like. Every house nowadays—at least, in London and the suburbs—of a rental of £45 or £50 and upwards must have its bath-room, with hot and cold water laid on. So also, in large country mansions, two, three, or more bath-rooms must be provided. And all these appliances must be arranged in the simplest and most obvious manner possible, not stuck on here and there as they may happen to be wanted. Nothing is easier than to make a house all corners, with bath-room here and a dressing-room or a boudoir there, in the place where they are least expected or wanted. Good planning demands care and application, but the result will, in the end, repay the time spent in working out the details. "In perfect planning expedients should never be obvious—no steps down into rooms, no corners cut out of apartments, leaving them an irregular shape, to form closets or give headway for stairs."* The parts must fit into their places like the pieces of a Chinese puzzle, and the result will be a unity of design, obtained, apparently, by the simplest possible means. "To produce

* "House Architecture," J. J. Stephenson, Vol. II., p. 49.

simplicity out of a number of complicated requirements is the last effort of art—the art which conceals the art." *

The arrangement and distribution of light are important items in house-planning. "Light (God's eldest daughter) is a principal beauty in a building, yet it shines not alike from all parts of the heavens. An east window gives the infant beams of the sun before they are of strength to do harm, and is offensive to none but a sluggard. A south window in summer is a chimney with a fire in it, and stands in need to be screened by a curtain. In a west window the sun grows low and over familiar towards night in summer-time, and with more light than delight. A north window is best for butteries and cellars, where the beer will be sour, because the sun shines upon it." † Light should be everywhere. A dark corner means dirt, and where the light does not penetrate, there, as a rule, the air does not circulate. Borrowed lights should be avoided, and a passage dark enough to require the aid of artificial light in the day-time is a thing not to be tolerated.

Ventilation and warmth are matters which are greatly affected by the plan of a house. Without trespassing on the subjects treated of in the sections under these heads, it may be pointed out that the plan should assist both the ventilation and the warming of the house by avoiding draughts and places where the air is liable to stagnate, and by grouping the smoke-flues in such a manner that they will add to the warmth of the house, instead of radiating their heat to the outer air.

And lastly, good planning, though it must never be subservient to, yet must always be accompanied by good architecture. To clothe the most admirably-arranged house with an exterior like a workhouse or a barrack of forty years since, is an outrage on good taste and an insult to society. To plant a hideous square box of a house with rectangular holes for windows and not one single line of beauty or grace in the whole, in the midst of a lovely country side, is a deed which cannot be defended on any grounds whatever.

* "House Architecture," J. J. Stephenson, Vol. II., p. 50.

† "The Holy State" (Chapter VII., "of Building"), by Thomas Fuller, D.D. 1642.

CHAPTER VI.

SERVANTS' OFFICES.

Some Isolation desirable in Servants' Offices—Kitchens—Influence of Various Floors upon Vermin—Kitchen Furniture and Fittings—The Scullery—Larders—Pantries—Servants' Hall—Housekeeper's Room—Cellars—Laundry—Stores.

In the small eight or ten-roomed villa the servants' offices consist solely of a kitchen and scullery, with perhaps a small pantry. The space available being necessarily small, it is the more necessary so to arrange it that every inch shall be utilised. It is even permissible to encroach upon the limited dimensions of the scullery in order to give more space in the kitchen; but care must be taken so to arrange the scullery that every corner of it is well lighted.

In houses of sufficient size to permit such an arrangement, the servants' department should undoubtedly be, to a certain extent, isolated from the rest of the house, though, for obvious reasons, not in the sense of placing them in a separate house. This is requisite, not only for the comfort and convenience of the family, but also for that of the servants; for in a properly-disciplined household no harm results from according to the servants a fair amount of privacy in their department. In a town house this end is invariably attained by placing the whole of the servants' offices in the basement. In country houses, the available extent of the site being ordinarily much greater than in town, the servants' offices should be at or above the ground-level, and should look on to a kitchen yard, or garden, if there is one; but in no case would it be convenient for them to overlook the private garden. Between the villa residence of modest dimensions, where the number of servants is three, four, or perhaps six, to the country mansion, where accommodation has to be provided for butler, housekeeper, footman, valet, cook, kitchenmaid, housemaids, laundrymaids, and ladies' maids, besides rooms available for visitors' servants, there are many gradations. But the leading principle of providing the different departments with the necessary facilities for the work to be done in each, without trenching upon the other departments, prevails alike in all.

The Kitchen.—This most important apartment must, before all things, be well lighted and well ventilated. The importance of good ventilation to a kitchen is obvious. Without it the smell of cooking—which must escape somewhere—will inevitably find its way into the living-rooms, and pervade, to a greater or less degree, the whole of the house. Good ventilation is also very necessary as a means of counteracting the excessive heat of the cooking apparatus. Where the kitchen is a one-storey building, the best arrangement both for lighting and ventilation is by the roof. A good lantern-light, with at least half the lights made to open, and with outside blinds on the south and west sides, is the most effectual kind of roof-light that can be had. Where a top-light is not to be had, the kitchen should be so arranged that it can be lighted entirely from the north or north-east, the windows taken close up to the ceiling, and means provided, by air-bricks or other appliances, for inducing a current of air through the room both at the ceiling and floor levels. In town houses, probably the best position for the

kitchen is at the top of the house. This, however, entails a rather elaborate system of lifts, speaking-tubes, and other appliances, and is only applicable to houses of the larger class.

When the kitchen is on the same floor as the dining-room it should be as near to that apartment as possible, without actually adjoining it, so as to economise labour in carrying the food, and also to prevent the too rapid cooling of hot viands in transit.

The size of the kitchen must necessarily vary with the size and requirements of the house to which it belongs. A kitchen 20 × 20 is ample for the requirements of a large establishment. Anything beyond this is more or less inconvenient, and therefore wasted space. When it is remembered how small is the "galley," or cook-house on board one of the Peninsular and Oriental Company's steamers, and some of the best Transatlantic vessels, and what a vast number of persons have to be served from it, and, moreover, what elaborate dinners are placed before the passengers, it will be seen that the size of a kitchen for an ordinary house need not necessarily be very extensive. Nevertheless, a small kitchen is not to be recommended; and, for a large establishment, a certain amount of space, beyond that which would suffice on board ship, is absolutely requisite. In houses where the kitchen has to serve also as servants' hall, the size must be proportionately greater than where it is used solely for cooking purposes. As a rule kitchens in small houses are inconveniently small, being, in truth, sacrificed to the living-rooms. A room which is the only sitting and eating room for two, three, or four persons, and where a fire, often a large one, is constantly burning for the greater part of the day, both in summer and winter, ought surely to be as large, or nearly so, as the dining-room. Yet the space thought sufficient by most speculating builders is frequently only about one-half that of the dining-room.

The kind of floor best adapted for kitchens is Portland cement. Where, however, the kitchen is used as a living-room, part of the floor is, for the sake of comfort, usually boarded. It is, however, almost impossible, with a boarded floor, to keep a kitchen free from vermin. The heat of the kitchen range seems to encourage the growth of black-beetles and crickets, and, with a wooden floor, every facility is afforded them to overrun the place. Probably the only way of preventing the evil is to have an absolutely impervious floor. A well-laid concrete floor, faced with Portland cement, or asphalte, is at once impervious and economical. The large red tiles, so often seen in farm-house kitchens, laid on a solid bed of concrete, make as good a floor as can be desired both for appearance and wear. Where a wooden floor is desirable, the wood-block paving, described in a later chapter, may be used, as, from the solid manner of its construction, it affords no harbour to vermin, and at the same time it is warmer than cement or tiles. The walls also should be covered with some impervious material. The best possible wall-covering is the ordinary glazed tile. With a simple-coloured border nothing can be more cheerful and clean in its appearance. The same effect can be obtained at a somewhat less cost by building the enclosing wall with glazed bricks. The appearance is not quite so satisfactory as that of the tiles, but the work has the advantage of being more solid. Where the contemplated outlay would not warrant the expenditure involved by the use of either of these materials, a hard impervious face can be given to the walls by using Parian or Keene's cement,

or by selenitic plaster with a selenitic clay finish. The selenitic process is as cheap, if not cheaper, than ordinary plaster, but requires care in mixing and measuring the ingredients. The prejudice which exists among builders against any departure from time-honoured rule-of-thumb processes will probably prevent the use of selenitic cement in speculative building for some time to come. Kitchen walls finished with the ordinary plastered surface should have the lower part painted and varnished to a height of about five feet from the floor. The upper part of the walls and the ceiling should be lime-whitened or distempered.

The fittings necessary for a kitchen will vary according to the size of the house and the amount of cooking required. The most important fitting is, of course, the range. So many different kinds of cooking stoves of such diverse patterns and sizes are now to be had, that it would be impossible here to describe them all, and to single out one or two where so many are really efficient would be invidious, as well as misleading. The old-fashioned open range, with its immense fire-bars, has been of late years much discarded for the sake of close stoves, or kitcheners, which have the minimum of fire-space. Both have their advantages and their disadvantages. A close stove may be more economical in point of consumption of fuel than an open one, provided it is managed with skill and knowledge, but in ignorant and careless hands it is an insatiable furnace. Close stoves have also the disadvantage of making the kitchen very hot, and unless proper precaution is taken with the setting, they are apt, when fixed in party or internal walls, to be somewhat dangerous.

Some of the American and other stoves, which stand on legs independently of any brickwork, and require no setting whatever, are both efficient and economical.

In kitchens of large mansions the range is usually a formidable piece of machinery. The close stove is inapplicable here, as a large surface of fire will be required for roasting several joints at one time. In addition to the range, boilers for steaming vegetables, bain-maries, and hot-plates will be required. In front of the fireplace a roasting-screen is placed, and the meat-jack is often fixed in the chimney and turned by the upward current in the chimney, hence called smoke-jack.

Where such an elaborate array of apparatus is not required, it will be useful to provide a gas stove at the side of the range as an occasional auxiliary thereto. Gas, however, is not to be recommended as a fuel for constant use, it being at present more costly than coal. The only advantage it possesses is that of being lighted and put out quickly. A good-sized coal-bunk should always be provided somewhere in the kitchen. When a kitchen is lighted by gas, it is always useful to have a jet fixed on one side of the range, and which can be turned on, so as to illuminate the whole of the recess in which the range stands.

The furniture of the kitchen should be strong and clean in appearance. Deal is perhaps the best wood for the dresser and table. Many old dressers are to be seen in farm-houses of ancient date made of oak, and really handsome pieces of furniture. The dresser, or dressers (there frequently being more than one), consists of a broad open shelf, with drawers underneath for keeping various articles used in cooking, supported on strong framework, with a board about six inches from the floor on which to stand saucepans and other metal vessels. The upper part contains tiers of shallow shelves, on which the plates and dishes in daily use are placed. The table should be a plain and strong

piece of furniture, and has usually a drawer at each end. The fewer drawers there are in a kitchen the better, as they are apt to lead to untidiness and accumulation of dirt. One good cupboard, placed in as light a position as possible, should furnish all the storage-room required in the kitchen by the cook. A serving-hatch from the kitchen to the corridor or lobby leading to the dining-room is a convenient arrangement, as it both shortens the distance between the two rooms and lessens the traffic in the kitchen.

In country houses, where the bread-making of the establishment is done on the premises, it is best to have a separate bakehouse with a brick oven. If, however, this cannot be arranged, an iron oven should be contrived underneath or at the side of the cooking-range. In either case a separate dresser with kneading-trough becomes a necessity. A separate room for pastry-making is also, in large establishments, frequently provided, the temperature of a large kitchen in which several cooking apparatuses are simultaneously at work being too high for manipulating pastry successfully.

The Scullery must be in immediate communication with the kitchen, and should be a good-sized light room, not a narrow, ill-lighted passage from the kitchen, as is often the case. The principal use to which the scullery is devoted is suggested by the name, which is probably derived from an old Danish word meaning shell or cup. Hence, also, scullion, an office which existed long before a separate room was provided for his use,* and whose principal function was the washing of cups. Besides the cleansing of plates and dishes, and of the various utensils used in cooking, the scullery ordinarily is the proper place for cleaning and preparing fish, vegetables, &c., and generally for processes in connection with cooking which entail dirt or litter, and should therefore be kept out of the kitchen. The walls and floor of the scullery, like those of the kitchen, should be formed of one or other of the impervious materials described above, the great object to be aimed at in both cases being a washable surface. The scullery must be amply lighted, and in front of the windows should be fixed the sinks. Where the use of glazed bricks or tiles over the whole wall surface is impossible on the score of cost, the walls at the back of the sinks should be lined with white glazed tiles. Three or four courses of tiles the whole width of the sink will suffice, and the small extra cost involved would be amply recompensed by the additional cleanliness gained. Where space would permit, there should be at least two sinks—one for vegetables, the other for plates and dishes, with a draining-board at the side over which the plate-rack should be fixed. It is convenient to have in the scullery a small cooking-range, to do duty both as an auxiliary to the kitchen range, and also when the latter is undergoing repair, or when only a small amount of cooking is required, as during the absence of the family. In small houses the scullery is usually the washhouse, and contains a washing-copper. Care should always be taken that the copper has an independent flue.

In large houses it is convenient to provide a knife-house, or place for cleaning knives, in immediate connection with the scullery, but in small houses this operation is usually performed in the scullery.

* Probably one of the earliest instances of the use of the term is in one of the Liberate Rolls of 21st Henry III. The King's Bailiff at Kennington (then a royal house) is there ordered to make "one Knight's chamber and a scullery" (squielerium).

Within easy distance of the scullery the fuel-store should be placed. There should be separate places for storing coal, coke, and wood. The wood-store ought to be large enough to allow room for chopping. The most common arrangement of coal-store is to provide cellars for the purpose. In towns, this is doubtless unavoidable, owing to the limited area available, but in suburban villas and country houses, where the site is large, it is better to form an outhouse for coals, so as to save the labour of raising them from a basement or cellar. If an outhouse be provided for the coals, it is convenient to arrange it so that they can be thrown in from an opening near the top. The waggon may be drawn up near the opening, or an inclined plank may be kept for the purpose. The coal-stores should ordinarily provide for the separate keeping of two sorts of coal, as it is rare that the coal used in the ordinary fire-grates is well adapted for use in the cooking-range.

Where it is possible, the scullery and kitchen should both communicate with a passage giving access to the servants' closet. In small houses, however, this is often impracticable, and the servants' closet has to be reached through the scullery. In this case the door of the closet should be outside the scullery, and the access thereto protected by a pent roof. Of course, where both male and female servants are employed, there will be a water-closet for each sex, with separate access to each.

The Larders.—The name larder, which has come to be applied to a store for all kinds of food, cooked and uncooked, was originally applied to the place where meat, which had previously been salted down, was put away in jars, and covered over with lard. The increased facilities for transport, and other causes, have, by bringing within reach of all large supplies of fresh meat, obviated the necessity for salting down provisions for winter consumption.

The larder must, before all things, be cool and of an even temperature. A north aspect is indispensable. It must also be dry: ample ventilation must therefore be provided. The windows should be filled with wire gauze in place of glass, and, if possible, through ventilation should be provided. It will also be useful to provide an inner casement of glass for use in very severe weather. The walls should be lined with glazed tiles or bricks, marble or enamelled slate; and the ceiling should be of concrete, brought to a hard polished surface with Parian or Keene's cement. Tiles, marble, bricks, slate slabs, or concrete, are all suitable materials for the floor. Shelves, either of marble or enamelled slate, and hooks depending from the ceiling for hanging joints or game must be provided. It will generally be found that, except in large establishments, one good-sized general larder will suffice. Separate larders for meat, game, and fish, however, are sometimes required; but care should be taken not to multiply store-places of this kind unnecessarily, and also to arrange them in as compact a manner as possible.

The Pantries.—The pantry (from *panis*, bread), formerly a room where bread and other provisions were kept, has now come to mean the apartment occupied by the butler or housemaid for cleaning and storing silver and glass. In large establishments the butler has charge of the silver, glass, cutlery, and all the china except the plates and dishes; and proper appliances in the shape of sink, draining-board, and hot and cold water service must be provided for the due cleansing of the various articles in his custody. A usual and convenient arrangement for a

pantry is to place the sink, &c., in front of the window, and the closets for china, glass, &c., against the opposite wall. Where there is a large stock of valuable silver, a fireproof safe is commonly provided for keeping it in; and where the pantry is on the ground-level, not in the basement, the butler's bed-room should be in immediate communication. In all but the smallest class of houses there should be some kind of pantry; even a fair-sized china-closet, with a small sink, will be better than none at all. The proper methods to be observed in getting rid of the waste water from this and the scullery sinks will be found in the section on drainage.

Servants' Hall.—The size of this room will vary with the number of servants to be accommodated. It should have a cheerful aspect, and be well lighted, warmed, and ventilated. It should be placed within easy access of the entrance-hall, and also close to the servants' entrance, so that it may be used as a waiting-room when occasion demands. The windows should be so contrived that, while they should not overlook the private grounds, they should yet afford a cheerful and pleasant outlook.

The Housekeeper's Room will, in large mansions, be an apartment of considerable size. It should be in proximity both to the kitchen and the store-room, and in some cases will have to answer the purpose of a store-room. It should be amply supplied with store-closets. In any case, it should be a well-lighted cheerful room, as it not unfrequently has to serve as the sitting-room for the upper servants.

A luggage-room will be a necessary provision in large houses. It should adjoin the side entrance, and be in the direct line between the front door and the stables. It may conveniently take the form of a vestibule to the side entrance, in which case it will serve as tradesman's hall.

The Cellars.—There ought to be no difficulty in providing ample cellar-space to the largest as well as to the smallest house. No house ought to be built without cellars under the whole area. This, of course, sounds extravagant to a degree, but it is nevertheless true. With well-ventilated, dry, and properly-constructed cellars, the evils arising from damp ground and the alternations of temperature common to most kinds of soils will be greatly neutralised. The external walls must of course be protected by a properly-constructed dry area, as described in the preceding chapter. The floor and the ceiling should be of concrete, or of bricks on a concrete substratum, and an ample supply of ventilating air-bricks, which may also serve for admitting light, should be inserted in the walls at the ceiling-level. Wine-cellars must be arranged in the position least subject to variations of temperature, and it is sometimes necessary to provide an outer and an inner wine-cellar. The wine-cellars should be fitted up with slate or stone shelves on brick supports, or with iron racks, and space for a table may be provided. Wine-cellars in large establishments are sometimes subdivided into store-cellars, dispensing-cellar, receiving-cellar, and cellar for wines in wood and for bottling.

Part of the cellars may occasionally be divided off to form a convenient box-room.

In all large houses not supplied with gas a room should be arranged for cleaning and keeping lamps and lamp-oil. As little woodwork as possible should be used in the construction and fittings of this room, and, consistently with doing the work properly, it should be as small as possible.

A separate room may also be provided for cleaning boots and brushing clothes. This room may be in the yard next the wood-house.

In this yard will also be placed the dust-bin. Properly, nothing but dry rubbish and ashes ought to be placed in the dust-bin. It should be of limited capacity, so as to necessitate its being frequently emptied and cleansed, and thus prevent any animal or vegetable matter that may be deposited in it from remaining there long enough to set up putrefaction. A strong barrel or tub with suitable handles, or a galvanised iron box, to stand under an open shed, is perhaps the best form of dust-bin; but where it is a fixed structure it should be constructed of substantial brickwork, rendered inside with cement, and should have a flagged or cement floor three or four inches above the level of the adjacent ground. Unless the dust-bin is under a shed it should have a sloping cover, with a self-closing lid so arranged that the rain should not be liable to penetrate to the inside. A useful addition to the dust-bin is a sieve with a stick passed through the sides of it to serve as a handle. The sieve rests on a couple of wooden bars near the top of the dust-bin, with the handle passing through the side of the bin. Ashes and cinders may be thrown into the sieve, the lid of the bin shut down, and by means of the handle the dust is riddled through the sieve, and the cinders can afterwards be collected for use in the fires. The position of the receptacle for dust, and other dry refuse, will be determined by various circumstances—as the size and character of the house, and the mode of collection. In all cases it should be as near as practicable to an entrance, and should be so placed that it can be emptied without involving the necessity of carrying the contents through the house. It should be placed as far away as possible from all windows. And if, as in the case of artisans' dwellings in towns, and dwellings on the "flat" system, it is necessary to keep a receptacle indoors, provision should be made for emptying the contents of each receptacle into a general receiver at least once in the day. For this purpose a lift will probably be found the most efficient appliance. Dust-shoots are objectionable, from their liability to get clogged, and the impossibility of ensuring their proper usage.

The Laundry.—The laundry offices may be placed either near the kitchen offices or away from the house, the advantage of one or other arrangement depending upon the special circumstances of individual cases.

They consist of washhouse, laundry, drying-room, and soiled-linen room.

The washhouse should be an airy, well-lighted room, with an open roof provided with ample ventilation by means of louvres at the highest point. Provision should also be made for the admission of fresh air either at the floor-level or about six feet above. The wall and floor must be of some non-absorbent substance—glazed bricks or tiles for the walls, and Portland cement or asphalte for the floor, being about the most suitable materials.

Provision should be made by means of open channels of glazed stoneware to carry off the water, when the floor is washed down, into a gulley grating situated outside the building.

The ordinary apparatus for a washhouse consists of a large copper for boiling linen, and, where machines are not used, as many washing-troughs as may be needed, each provided with a supply of hot and cold water. Wooden standing-boards should be provided in front of these troughs, which should be placed in front of the windows. It may also be necessary to provide space for washing and wringing machines.

The laundry should communicate with the washhouse, and should be constructed in a similar manner, except that the floor may be of wood. The apparatus of the laundry will be one or more ironing-tables, a mangle, and an ironing-stove.

In most laundries the drying is now usually done in closets or rooms specially arranged for the purpose. The wet linen to be dried is arranged on a series of upright frames placed side by side, and which slide out into the washhouse and laundry. When covered with wet linen in the washhouse, these "horses" are slid back again into the drying-closet, in the floor of which are a series of coils of pipes, by means of which the requisite temperature is obtained. The drying-horses are afterwards drawn out into the laundry, where the dried linen is removed from them. Due provision must be made for the escape of steam from the drying-closet.

The room for soiled linen will be a small but well-lighted room, with a wide shelf for sorting. By preference, this room should be long and narrow, with the light on the long side.

Such laundry offices as described above are suitable for large country houses. In houses of a smaller kind—as, for instance, an average country rectory—a wash-house is all that can usually be provided.

The great importance of thorough ventilation, and ample lighting, to the smallest as well as to the largest laundries, can hardly be too strongly insisted upon. And in the case of a room used solely for the reception of soiled linen, it is obviously of the highest importance to secure the possibility of thoroughly changing the air of the room in a short space of time.

Where shoots are used for conveying soiled linen from upper storeys to the ground, it is desirable to fit them up with canvas lining that can easily be removed for cleaning.

Stores come under two heads. The first may be classed under the general head of grocery or dry goods, the second under that of linen.

The store-room proper is usually placed among the servants' offices, and, where there is a housekeeper, is in her charge. Tea, sugar, coffee, rice, preserves, candles, and many other things necessary either for the kitchen or other parts of the house, are here stored. It will therefore, even in a house of moderate extent, be a fair-sized room. It should be fitted up with large and deep drawers and shelves all around, and a strong deal table, on which to stand the various canisters and other vessels in use when stores are being given out. Space should be provided for barrels, and for the large earthenware pans in which sugar is kept. Lastly, the room should be thoroughly dry; there should be ample light and ventilation, and the aspect should, if possible, be north.

The linen-room is best placed near the bed-rooms. Of course, in the smaller kind of houses it must necessarily be a mere closet with shelves; but where space will admit it ought to have a window, however small. In large establishments the stock of linen (in which term are included blankets and counterpanes) will be very extensive. The linen-room should be large enough to contain the whole store of linen on shelves, or in presses along the walls, and to afford space for a table in the centre for examining, sorting, and marking linen. There should also be a fireplace, or, at any rate, some means of warming the linen-room, and keeping it dry. This can often be managed by taking the hot-water pipes which supply a bath through

the room. A small pedestal stove might be fixed in the centre of the room on a proper stone or metal hearth, and the pipe taken about 1 ft. 6 in. above the floor to the chimney-flue. A wire guard should then be fixed over the whole length of pipe, on which linen might be aired along the entire service.

This exhausts the list of domestic offices proper. The important points to be borne in mind in arranging the servants' offices are, first, that they should be as light, cheerful, and comfortable as possible, so that the work which has to be done in them may be performed under conditions most conducive to health and economy of labour, which last item, in these days of scarcity and expensiveness of domestic servants, is every day more important, especially in small establishments. And secondly, that all fittings and appliances, of whatever kind and for whatever purpose, should be as strong and simple in construction as possible.

CHAPTER VII.

THE LIVING-ROOMS.

Entrances and Passages—Staircases—The Dining-room—Drawing-room—Breakfast-room, Boudoir, and other subsidiary Rooms.

The position and arrangement of the principal entrance to a house is a point of very considerable importance, being, as it were, the key-note to the whole. A grand and spacious hall, giving access to small and mean-looking rooms, is as great an offence against good taste as the opposite extreme. The impression left on the mind in either case is that of incongruity.

The entrance-door in terrace houses of the smaller kinds, where the ground floor contains but two, or at most three, rooms, must necessarily be in the front; but in semi-detached houses, and in cottages, there is more scope for variation, if, as it often may be with advantage, the main entrance be placed at the side. In the case of a corner house, in a row of terrace houses, for instance, this will obviously be the case, as not only will less room be devoted to mere passage, but, by a little attention to the details of planning, the entrance-hall and staircase may be made to appear more spacious, while in reality occupying less space than those in the adjoining houses with doors in front. Another advantage will be the additional size of the front sitting-room. In the case of semi-detached houses with a basement floor, the advisability of entering at the side will depend greatly on the width of the ground on which the house stands, as space must be left at the side of the steps leading up to the entrance-door, to afford access to the back door and the gardens, and also to allow of the contents of the dust-bin being removed without passing through the house. In situations where the value of land is not as great as it is in the immediate neighbourhood of most large towns, it is not unfrequently the custom to arrange the smaller kinds of houses without a basement, and so to place the sitting-rooms one on either side of the front door, with the kitchen offices at the back. This kind of house, known commonly as "double-fronted," is much sought after and peculiarly beloved by matrons, as presenting the appearance of a much larger house than it is in reality. As a matter of fact, most of these houses could be vastly improved by relegating the entrance-door to a more modest position at the side, and adding the space thus gained to the front rooms.

In planning the front or entrance-door to a small house, of whatever kind, it is most important to keep well in view the position of the staircase, and, in fact, to plan both door and staircase together, as, in order to obtain a successful result, it will be necessary to utilise to its utmost extent every available inch of space.

The front entrance should, in large houses, as a rule, be placed on the opposite side of the house to that on which the principal sitting-rooms are placed. It will thus be more readily accessible from the servants' side of the house, and the sitting-rooms will not be overlooked from the carriage-drive. Circumstances of site, aspect, and approach have each their influence on the position of the principal entrance, so that in houses above the suburban villa class no strict rule can be laid down on the subject. In houses of the villa class the choice is limited between a front entrance

and a side entrance. Both have their advantages, which will be more clearly shown when the planning of special kinds of houses is under consideration. The subordinate entrances consist of the tradesmen's entrance, the garden entrance, and the door to the kitchen yard. To these may be added a separate entrance to the business or justice-room in large mansions, and to the parish-room in rectories.

The front entrance-door should give access to a vestibule, on one side of which a cloak-room with lavatory and water-closet should be arranged. On the other side, where possible, should be the communication with the servants' quarters. It is also usual in large houses to have a porch large enough for carriages to be driven underneath, so as to set down under cover. For want of a better name, this is usually called a "*Porte-cocher.*"

The hall will, of course, be more or less spacious, according to the size of the house. In country houses it not unfrequently serves as the billiard-room. In any case, except where it is a mere passage, it should be capable of being furnished, and used as a sort of extra sitting-room, and should have a fireplace. The hall may also be taken up two storeys in height, and have a gallery round it, giving access to the upper rooms. The staircase, too, can be made to form an important feature in the hall. In fact, there is scarcely any limit to the amount of architectural display of which this part of the house is susceptible. Where the space will permit, which is the case in all houses except those of the smallest villa type, the hall with the entrances to the different reception-rooms should be shut off from the rest of the house. Access to the kitchen and servants' offices will be most conveniently placed near the dining-room, an arrangement which will permit of the servants reaching the dining-room or serving-lobby without crossing the hall. The offices can be arranged on either side of the passage, or in the form of a quadrangle with the passage on the inner sides. The passages and thoroughfares in the upper floors vary in extent with the size and number of rooms on each floor. No very stringent rules can be laid down for the arrangement of passages where so many diverse conditions and possible requirements exist. It may, however, be taken as an absolute rule, without any exception, that passages must be lighted directly from the open air. They should also be as broad as circumstances will admit. Where such a lavish expenditure of space is permissible, the passages may be wide corridors or galleries, with recessed windows, in which seats can be arranged. In planning the passages, especially in small houses, economy in the matter of carpets should receive due attention. This remark will apply equally to the staircase.

Staircases.—Lord Bacon's idea of what a staircase should be is worth quoting here :—"The stairs, likewise, to the upper rooms, let them be upon a fair open newel, and finely railed in, with images of wood cast into a brass colour ; and a very fair landing-place at the top."* The "fair open newel" is evidently a reference to the open staircases, first constructed in Queen Elizabeth's reign, which succeeded the old Gothic staircase built round a solid stone wall, and often circular on plan. That the open arrangement was a vast improvement on the old corkscrew staircase will not be denied. The principal staircases in many of the old Elizabethan mansions which remain to us are patterns of what the staircase ought to be. Usually constructed entirely of oak, the steps wide, and with a well-proportioned rise, square landings, and with handsome carved balusters and handrail, they form an imposing feature in

* "Essay on Building."

the house. Frequently the top landing forms a gallery, giving access to the rooms above. Two very common faults are to be found in staircases, especially in small houses. They are, first, stairs in long flights without any break or landing; and secondly, what is usually a consequence of the first, "winding" steps. The staircases shown in M. Violet-le-Duc's book, "How to Build a House," exhibit each of these faults in a marked degree. The principal staircase is in one continuous flight, with winding steps at each end, and the secondary staircase is all "winders," being, in fact, the old mediæval turret staircase reproduced. With care in planning, and a little additional space allotted to the stairs, both these faults may be avoided. There ought to be a landing to at least every six feet of vertical height. Two intermediate landings in a height of eleven or twelve feet would be better still. As to "winders," under no consideration whatever should they be tolerated. The proper gradient for the steps is a very important element in setting out a staircase. The scale which is found in practice to be best is given under "Interior Construction." Palladio says that steps should not exceed six inches, nor be less than four inches in height. The breadth he gives at not less than twelve inches, and not more than a foot and a half. These dimensions seem to err in making the steps too low and wide, and thereby increasing the exertion necessary in ascending. Grand marble or stone staircases admit, however, of a smaller rise than less pretentious ones. Six inches rise and eleven inches tread afford, perhaps, the most practicable stair for ordinary use. The back stairs, and stairs in small houses, where space is necessarily limited, may have "risers" as high as seven and a half inches, with treads nine inches wide. Stairs to lofts, which approach more to the character of a step-ladder, may be somewhat steeper even than this.

The back stairs are for giving access to the bed-rooms from the servants' offices without using the principal staircase. In town houses they are often arranged to work in behind, or at the side of the principal staircase. In all houses where it is possible a back staircase should be provided, and in immediate communication with it the housemaid's sink should be arranged. Additional staircases must be provided where, under some other circumstances, the arrangements of the house require, as for a nursery stair, and one for access to the men-servants' bed-rooms.

The Family Living-rooms.—Between the labourer's cottage, with its one living-room serving also as kitchen, and the mansion of a nobleman, with its suites of reception-rooms—"a Side for the Banquet, as is spoken of in the Book of Esther, and a Side for the Household" *—there are many steps; but inasmuch as there are certain fundamental rules which govern all the various classes of houses intermediate between these two, the requirements of such rooms only as are common to all, or nearly all, can here be defined.

The Dining-room.—The best aspect for a dining-room is south-east, or south-south-east. This allows the sun to shine into it in the morning, which, when the room is used also as a breakfast-room, as it usually is, is pleasant enough. In the evening, when people are dining, the effect of the sunset is seen without the inconvenience of direct rays penetrating into the room. A westerly or south-westerly aspect is therefore to be avoided. A dining-room should be oblong in shape, and the windows may either be placed on one of the longer walls, or at one end.

* Bacon, "Essay on Building"

The former arrangement is perhaps more suitable for large rooms, and the latter for small ones.

Fig. 23 represents a plan of a dining-room thirty-two feet long by twenty-four feet wide. The windows (W W) are placed on one of the longer sides. The fireplace (F) is at the end opposite the sideboard; A is the door leading to the other reception-rooms; B, that to the serving-room.

Fig. 24 shows a room twenty-four feet long by sixteen feet wide. The whole of the end wall is occupied by one large window, or a bow-window, as indicated by the dotted lines, might be formed. At F is the fireplace, and at D the door.

It should be noted that a room of this shape can be lighted with fewer

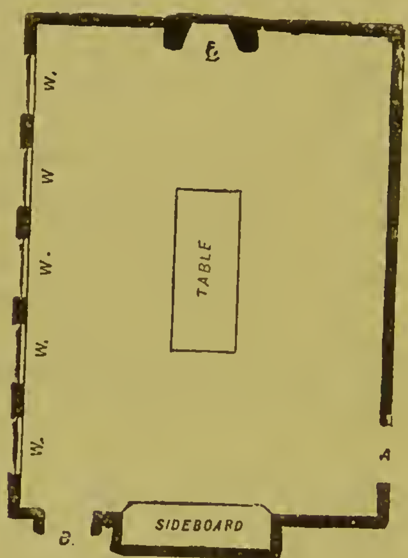


Fig. 23.—Dining-room.

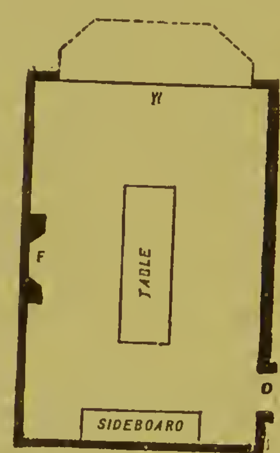


Fig. 24.—Small Dining-room.

windows if they are placed on one of the sides than would be necessary if the end wall only be used for the purpose.

The dimensions of a dining-room should be arranged with a view to the purpose for which the room is to be used—namely, for meals. The size and position of the furniture—more particularly the table—must therefore be carefully considered. A dining-table is usually about three feet six to four feet wide; sometimes more. Taking the width at four feet, a space of one foot nine must be added on each side for people sitting at table. This gives a total width between the backs of the chairs of seven feet six inches. A three feet passage-way on each side is the minimum. This gives a dimension of thirteen feet six inches clear of the projection of the chimney-piece. Fifteen feet is a better size, and if length be added in proportion, any width between that and twenty-four feet is clear gain. A dining-room twenty-four feet by thirty-two feet may be called a grand room. The best rule for proportion of length to breadth is probably about three to two. Thus a room about fifteen feet wide should be twenty feet long. Less length will suffice, but for appearance a room of that width should certainly be not less than eighteen feet long.

If, as is usually the case in small houses, the fireplace, with its projecting breast and chimney-piece, is on one side of the room, the window, or windows, being

at one end; the gas-pipe, or hook for chandelier, in order to be over the centre of the table, should be fixed centrally between the projecting chimney-breast and the opposite wall, without regard to the centre of the window. As a rule it is placed centrally either with the window, or, if there are two windows, with the pier between them. The effect of this is either that the table has to be placed inconveniently close to the fireplace, or else that the lighting arrangement, whatever it may be, will be over one side of the table. In small houses, unless the central pendant light be dispensed with altogether, this is a point well worth noting.

Immediately adjoining the dining-room is the serving-room, where space will allow of such a convenience. Where the kitchen is in the basement there should be a lift large enough to contain dishes, and fitted with an automatic check to regulate it in going up and down. A hot closet for keeping plates hot should be provided in the serving-room. The communication between the dining-room and the serving-room may be either by a door or by an opening in the back of the sideboard.

The pantry may with advantage open out of the serving-room, and where there is a basement-kitchen the staircase thereto should be close at hand. Besides the hot closet, the serving-room should contain a shelf, and possibly a small table. Where there is not sufficient space for a serving-room, and the dining-room is large, the hot closet may be placed at one end of it, where it will be useful as an additional means of warming. This arrangement, however, would have the disadvantage of being intolerable in hot weather. In small houses, and where the kitchen is on the same floor as the dining-room, but not actually adjoining it, a serving-hatch is a great convenience, as it obviates the necessity for frequently opening the door. This provision obviously pre-supposes that at least two servants are kept.

The Drawing-room.—The aspect of the drawing-room, which is largely used in all kinds of houses in the afternoon, should be sunny and cheerful. South, west, and south-west, are all suitable aspects, with proper appliances in the shape of

Fig. 25.—Drawing-room.

verandahs, and sun-blinds outside the windows, to screen off the glare and heat of the midday sun. Nothing can be more cheerful and pleasant than to sit in a cool room and look out on to warm and bright sunlight without being affected by the direct rays. The dimensions of a drawing-room are susceptible of greater variation than those of a dining-room. Where there is no other room available for assemblies

the size must be somewhat governed by the extent to which it is likely to be used for receptions and entertainments. A very convenient arrangement, where there is plenty of space, is to divide one end of the room, enclosing a space either square, or nearly so, by columns, forming the portion marked B in the annexed plan (Fig. 25) into a boudoir or morning-room. With a separate fireplace, it makes a more cosy sitting-room for two or three people than the larger room. The drawing-room admits of any number of recesses, alcoves, oriel or bay windows, all of which afford facilities for the company to form themselves into groups for conversation, &c.

If there be a conservatory the drawing-room may communicate with it, but not directly. Charming arrangements can be made by two or more drawing-rooms, music-room, sculpture-gallery, orangery, and conservatory *en suite*, opening one out of the other.

Every house of any pretensions above those of a cottage has nowadays its third room, called either morning-room, breakfast-room, study, or library. By whatever name it happens to be called, it is a very useful adjunct, and should be arranged wherever space will allow. This must not, however, be at the cost of sacrificing needful space in the kitchen arrangements.

In large houses these additional rooms will often be several in number, and of some importance. They may comprise library, boudoir, morning-room, billiard-room, business-room, gun-room, and possibly music-room. The library, if it is to be really a library, and not a mere smoking-room, should be situated in some quiet corner, where its occupant can, if desired, be secure from interruption. It should not be capable of being used as a passage from one room to another, though a doorway of communication with either the dining-room or the drawing-room is by no means a disadvantage. The doors should in either case be double. The principal purpose for which a library is needed being the storage and study of books, the room should be planned with a view to these purposes. It must be dry and well lighted, but not exposed to direct sunlight. For this reason a north or north-east aspect is best suited for it. Plenty of wall-space must be provided for bookcases, and the bookcases should be all arranged for, and form part of the permanent architecture of the room. The windows, if deeply recessed, and of sufficient width, form convenient places for reading or writing, and, when so arranged, should each have a broad seat. Some of these windows may conveniently be fitted up with shelves for opening very large books upon.

The boudoir, or morning-room, is practically the same room with different names. It should be light and cheerful in aspect and appearance. A boudoir is often made an adjunct to a bed-room suite, or it may form part of the drawing-room suite. The shape best suited for a boudoir is probably square, or nearly so. Fifteen to eighteen feet each way is about the most suitable size.

The billiard-room is nowadays an invariable adjunct to all country houses of any pretension. It should be lighted from the roof wherever it is possible to do so. The best method of accomplishing this is by a lantern-light with sloping sides, or by wide windows, close up to the ceiling, along three sides of the room. These windows should be placed some six or seven feet above the floor, and should be as close together as can be managed. The proper means to be adopted for preventing the rain from making its way in and falling on the table, and also for carrying off the moisture of condensation, will be found described under "Interior Construction."

The lantern-light is preferable to an ordinary skylight, as the light, while quite sufficient, does not fall on the players and the table in a vertical direction. The size of a full-sized billiard-table is twelve feet by six feet, and at least five feet all round it is necessary to allow the cues to be worked. This gives a clear space of twenty-two feet by sixteen feet, which is the minimum size for a billiard-room. Twenty-four feet by eighteen feet is, however, better, and additional space may with advantage be provided where practicable, to enable spectators to watch the game with comfort. This may be done very effectively by a projecting window, or a recess in one side or end of the room. In forming the floor of a billiard-room it is important to secure a solid foundation for the legs of the table, in order to prevent vibration. If near the ground, this can best be done by forming two parallel nine-inch dwarf walls, five feet nine inches apart from centre to centre, to take the legs lengthways. If, however, the room is in an upper storey it will be necessary to introduce three rolled iron joists of adequate strength across the width of the room, at distances apart of six feet from centre to centre, if the table has six legs, and four joists if it has eight legs.

Where a music-room is required it will probably be a room of some size and pretension. If an organ is contemplated the height of the room will have to be considered in connection with the height of the organ. Probably the best shape for this room is a long and comparatively narrow one. The materials of which the room and its decorations are formed should all be selected with a view to increasing its acoustic properties.

A Smoking-room has sometimes to be provided, and possibly two. At Cardiff Castle, in the new tower designed by the late Mr. Burges, A.R.A., there is a summer smoking-room and a winter smoking-room. But this is a refinement of luxury permissible only to the few. There should be, in close proximity to the smoking-room, a suitable lavatory; a water-closet may likewise be provided in connection therewith.

Several of the most usual kinds of living or day rooms have now been enumerated, but there are others, of which mention has not been made—such as picture-galleries, sculpture-galleries, and ball-rooms—which have at times to be arranged. These, however, appertain only to houses of palatial type. It is also sometimes necessary to have separate suites of rooms for entertainments. All these things have to be considered in their turn, but underlying the whole subject of the arrangement or planning of living and reception rooms is the fundamental rule that each room must be carefully planned with a view to its special occupation or use. As a dining-room cannot be satisfactorily planned without the position of table, sideboard, door, fireplace, and windows being carefully thought out, so neither can a billiard-room be designed without taking account of the billiard-table and the space around it, or a library without arranging the position of the bookcases.

CHAPTER VIII.

BED-ROOMS, NURSERIES, AND BATH-ROOMS.

General Requirements of Bed-rooms—Dressing-rooms—Nurseries—Suites of Nursery-rooms—Servants' Bed-rooms—Bath-rooms and Water-closets.

The rules to be observed in planning bed-rooms are, first, that the bed should be placed in such a position that the air can have free circulation all round it without its being in a draught; secondly, that the door in opening shall screen, and not expose, the bed; and thirdly, that sufficient window-space should be provided, without overdoing the lighting, or rendering it an absolute necessity for the bed to face the light. It should always be borne in mind, moreover, that every bed-room is a possible sick-room; for a person ill in bed to have a window directly opposite his eyes is to the last degree trying. On the other hand, when the patient is well enough to read, a window on one side of him is just what he requires. It has been said above that the windows to bed-rooms should not be overdone. It is a common fault in modern houses to overwindow the bed-rooms, and a most inconvenient fault it is, as it greatly increases the difficulty of finding suitable positions for the furniture, and of maintaining an equable temperature. In houses of the villa type it is often next to impossible to avoid placing the bed either opposite the window or directly in the draught between the door and the window. In this case the former alternative should be preferred. A bow or square projecting window is a useful addition to a bed-room, giving space for the dressing-table, and leaving more free floor-space—a very desirable point to attain. Again, bed-rooms should always be capable of being used as sitting-rooms. This is more especially the case with spare bed-rooms or visitors' rooms. Where space will admit, proper accommodation should be provided for a writing-table, easy chair, and sofa, besides the ordinary furniture of the bed-room. Wardrobes ought to be made part of the permanent construction of the room, and not, as is usually the case, separate pieces of furniture. Recesses can often be formed and fitted up as wardrobes. Thus three large collecting surfaces for dust, at the top, between the back and the wall, and underneath, will be abolished.

Bed-rooms in large houses may often be conveniently arranged in sets. Thus one set may be appropriated to bachelors and another to young ladies.

In all houses where it can possibly be arranged, one or perhaps two rooms should be so planned that they can be used as sick-rooms. This is especially desirable in cases of infectious fevers, or where absolute quiet is necessary. They should be capable of being shut off by a lobby from the rest of the house, and a water-closet and slop-sink should be so arranged that in cases of illness they could be appropriated entirely to the use of the sick-room. Independent access as far as practicable should also be contrived, in order that communication with the sick-room may be had with the least possible risk.

The principal bed-rooms in all houses, even in the smaller class of semi-detached villas, usually have a dressing-room, and sometimes two, attached to them. Separate access must in all cases be provided to the dressing-rooms, inasmuch as, if entered only through the bed-room, half the value of a dressing-room is lost. A dressing-

room should always have a fireplace, and should not, as is often the case in London houses built a dozen years or so ago, contain the only bath in the house. A complete bed-room suite in a large house will often consist of the bed-room, two dressing-rooms, a boudoir, a bath-room, and a water-closet.

Nurseries.—The nursery department should always be placed within a convenient distance of the bed-room of the parents. At the same time it should be effectually shut off from the rest of the house. This is essential for the comfort both of the elders and of the children: for the elders, because, however fond people may be of children, there are times when the noise and unrest essential to childhood become wearisome; and for the children, because an undue restraint on their amusements, especially in the point of noise, is both unnatural and unfair. The

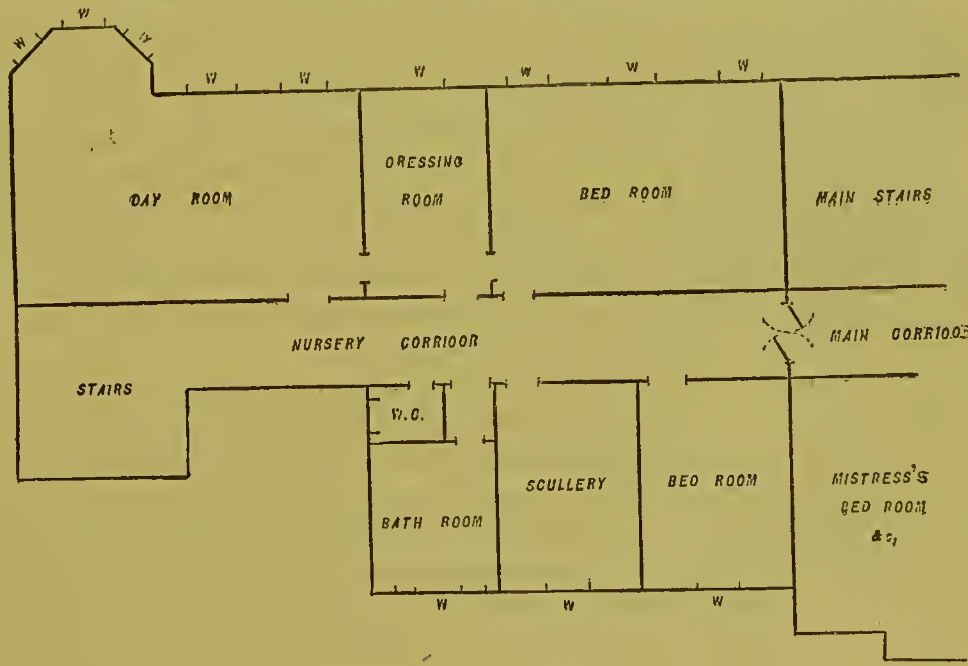


Fig. 26.—Nursery Suite.

nurseries, then, should be so shut off from the rooms occupied by the adult members of the family and the visitors, that the children can play and make what noise they please without fear of correction.

Very often the nursery must consist of a couple of rooms at the top of the house, taken much as they are. What can be done, or should be done, with such a nursery, as, indeed, with one of any size, will be treated of in detail by Dr. Squire, whose province it is to treat of whatever nursery may be ready to his hand. Here it can only be pointed out that a perfect nursery suite, on a large scale, should consist of a day-room, a bed-room for the head nurse and two or three younger children, two or three additional small bed-rooms for the elder children and the under nurse, a dressing-room, a scullery, a bath-room, and a water-closet.

The day-room should be a well-lighted, cheerful room, with a sunny aspect. The look-out should be as interesting as possible to the children, and every means should be taken to make the aspect of the room as bright and cheerful as possible. A cheap and effective mode of attaining this end is to cover the walls with some plain and simple paper-hanging, with a very unobtrusive design, and on this, at suitable

intervals, to paste coloured pictures. The selection of these should be made with care in order to accustom the children's eyes to good drawing and harmonious colouring. The whole of the walls, pictures and all, can then be varnished over, and a clean washable surface will be obtained.

A projecting window, either square or of the "bow" form, is a useful adjunct to the day-room, forming a convenient place for the nurse's work-table, and in which she can sit and work while the children have the whole floor-space for their games. A well-constructed stove, but which shall not be available for cooking purposes, must be provided, and a guard somewhat in the form shown in Fig. 27 firmly fixed to the chimney-piece, to serve the purpose both of fender and guard. The curved top might hinge to fall downwards, in order to give access to the fire. The extra rod sometimes fixed in front of the ordinary nursery fire-guards for airing linen should on no account be permitted; on the contrary, every obstacle should be put in the way of this undesirable practice, which, for reasons given when treating of the nursery specially, should never be carried on in the nursery living-rooms. The windows should be low enough for the children to be able to look out, proper precautions being taken by bars or wire blinds to prevent accidents.

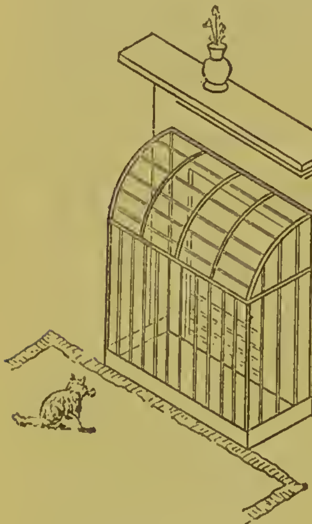


Fig. 27.—Fire-guard.

The bed-room should adjoin the day-room, and may communicate with it either by a door or by a window opening for ventilation. The maximum accommodation to be provided may be taken as for a nurse and four children. Calculating on a basis of 1,000 cubic feet per head, we have a room 30 ft. long, 16 ft. wide, and 10 ft. 6 in. high. This perhaps is somewhat extravagant. Reckoning two children to the cubic space of one adult, the total cubic space is reduced to 3,000 feet, which gives a room 20 ft. by 15 ft., and 10 ft. high. In a room of these dimensions (Fig. 28) the fireplace should be put in the opposite wall to that in which the door from the passage is formed. An aperture should be formed under the door that the air may be constantly flowing from the passage to the fireplace. By this means a constant stream of air at the floor-level can be kept up all through the night. The window in the bed-room should be at least three feet from the floor, and should be continued up to the ceiling-level. No closet or unnecessary recess should be formed in the bed-room, which is to be regarded simply as a dormitory, and must contain nothing but the beds.

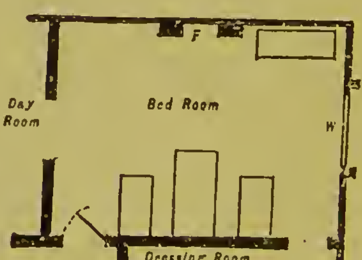


Fig. 28.—Nursery Bed-room.

Adjoining the bed-room, and in immediate communication therewith, is the dressing-room. This room should be of sufficient size to contain a dressing-table and a washstand. It may also contain the bath and a press or wardrobe for the nurse's and the children's clothes. The bath, however, is better in a separate room. There should be a fireplace in the dressing-room, and a gas-jet with an appliance for heating a kettle or saucepan.

The small bed-rooms, being designed for children old enough to wash and dress

themselves, must be of sufficient size to hold the usual furniture of a bed-room. About ten feet square will be adequate for these rooms.

The scullery is the apartment where any cooking that may be necessary is done, even to the boiling the nursery kettle for tea. A small cottage range with an oven should be provided, and a supply of hot and cold water laid on. The crockery in use in the nursery should be stored and cleansed in this room. It will therefore be necessary to provide a china-closet and sink for washing up. The scullery, too, is the proper place for airing the nursery linen; sufficient space must therefore be arranged in front of the fireplace for a good-sized clothes-horse. A galvanised iron coal-bunker of sufficient capacity for a week's consumption of coal may also with advantage be provided. Lastly, a closet for brushes and brooms and a slop-sink should be arranged in connection with this room.

The bath-room is a most useful adjunct to the nursery department, serving to keep the inevitable mess of a portable bath out of the day-room, and also greatly to economise labour. It is desirable that some means of heating should be provided, either by a coil of hot-water pipes, or by a small stove.

The water-closet must be cut off as much as practicable from the other rooms; if possible, this should be done by means of a lobby, with windows or air-gratings, however small, on each side, to ensure cross ventilation.

In arranging the staircase to the nursery (where space will permit of a special staircase), regard should be had to the fact that children's legs are shorter than grown people's, and consequently that a stair arranged for adult legs is steep and toilsome to the little ones. At the risk of being condemned as extravagant, it may be asserted that no staircase intended specially for children ought to have steps of a greater rise than four inches. A special handrail at a lower level may with advantage be fixed; and both rails should be formed in such a manner that sliding on them should be an impossibility. A small gate with a good spring latch, out of reach of the younger children, should be provided at the top of this staircase.

The nursery suite described above is one of a very complete and even elaborate kind, and one only possible in cases where the necessarily large outlay could be made. By a careful application of the principles to be observed in the arrangement and internal economy of the nursery, enunciated later on, the various parts may be condensed and simplified. Where, as is usually the case in small houses, two of the ordinary rooms of the house have to be applied to the purposes of the nursery, it must be an absolute rule that neither of these rooms shall be in the basement.

The school-room may conveniently be placed near the nursery suite, and the bed-rooms of the elder children, and of the governess, should be arranged in proximity thereto. Good light is an essential to a school-room, which should be somewhat longer than its width, with the windows arranged on one of the longer sides. "A complete bed-room suite has all the requirements necessary for a school-room suite, and may be appropriated to this purpose, the dressing-room being the governesses' bed-room."*

Servants' Bed-rooms.—The sleeping accommodation provided for servants is too often of a very objectionable character. Ill-lighted attics with sloping roofs, often

* Stevenson's, "House Architecture," Vol. II., p. 73.

with quite an inadequate protection from cold and heat, and rarely provided with fireplaces, are frequently appropriated for this purpose. Or if not attics, they are basement rooms, quite unfit for sleeping apartments. Servants have a right to expect that their bed-rooms should be properly lighted and ventilated, not by sky-lights, but by good windows—in short, that they should be healthy. At the cost of diminishing the floor-space, all rooms in the roof should be made with upright sides. Each room, however small, should have a good-sized window, which must be made to open both at top and at bottom. In large houses the female servants' bed-rooms should be grouped together, the principal servants having separate rooms, and the housekeeper's bed-room being placed in such a position that she has the rest of the rooms under her control. A bath-room should be provided for the use of the female servants, where circumstances permit. The men-servants' bed-rooms will not, as a rule, be so numerous as those of the women-servants. In country houses the men may conveniently be placed on the ground floor, the butler being put close to his pantry and the plate-safe. Rooms will likewise have to be provided for visitors' servants. An arrangement like the cubicles in school dormitories may, as Mr. Stevenson suggests, be conveniently made for this purpose. A long room, divided by boarded partitions into compartments, each about six feet by ten feet, and each provided with bed, washstand, and shelf to serve as dressing-table, will be found a more convenient arrangement than several small rooms, and more economical of space.

Bath-rooms and Water-closets.—Nowadays, every house of a rental value of £45 to £50 a year and upwards has its bath, with hot and cold water service.

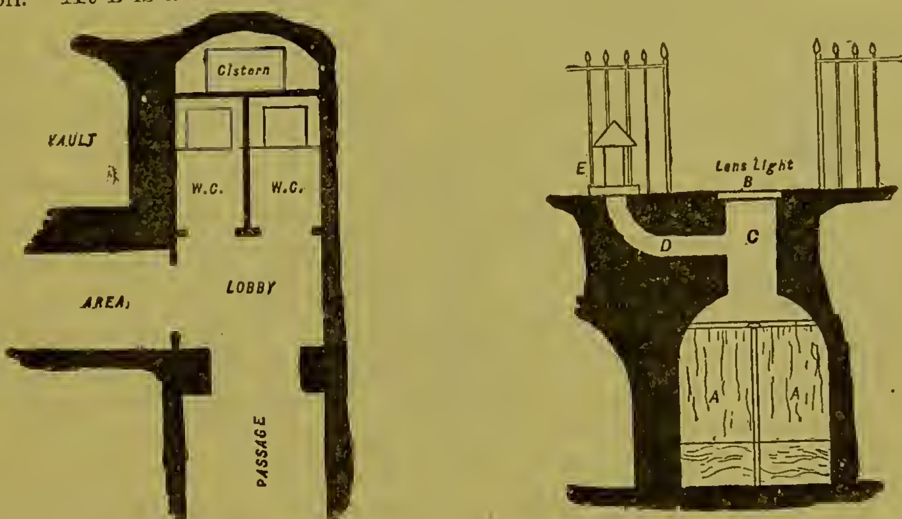
The advantages of bath-rooms with proper water-supply over portable baths, both in point of convenience and economy of labour, can scarcely be overrated.

In small houses there is no reason why the bath-room should not also contain the water-closet. It is, of course, better to separate the two where sufficient space can be had. In large houses a bath-room should be attached to each of the principal bed-rooms, and to the young ladies' and the bachelors' sets. The power of supplying hot water from the kitchen is, however, limited. It would probably often answer the purpose sufficiently in the bachelors' set to provide a bath to each room with cold-water supply only.

Water-closets should be arranged as much as possible one over the other, for convenience both of water-service and of ventilation. They should also be cut off from the main house by well-ventilated lobbies. Free ventilation and ample light are essentials to a properly-arranged water-closet. The old system of making the windows to the water-closets of a size proportionate to the size of the closet is as unwholesome as it is absurd. Water-closets should, if possible, have two windows, one facing the other; where only one can be provided, it should be so arranged as to cast ample light on the seat. Of course, these windows should open directly into the external air.

The number of water-closets requisite depends upon the size of the house in which they are fixed. It is usual in all but the smallest houses to have at least two—one for the family and one for the servants. As the size and accommodation of the house increases so will the number of water-closets be increased, until, in large mansions, a very considerable number will be required. Where men-servants are kept a separate closet and urinal should be provided for their use in a position apart from

that appropriated to the use of the women-servants. In town houses it is often unavoidable to fix one water-closet in the vault under the pavement. The difficulty, then, is how to light and ventilate such a closet. The following plan (Fig. 29) shows an arrangement successfully carried out in a house occupied by a number of young women engaged in business. A A are two closets separated by a wooden partition. At B is a cast-iron frame one foot ten inches square, fitted with Hyatt's



Plan. Section.

Fig. 29.

patent lens lights, which, by means of the shaft C, gives ample light to both closets. A branch shaft (D) acts as a ventilator, and is fitted with a fixed cowl at E. The disadvantages of a closet without very direct communication with the outer air, and where even borrowed light would be insufficient, have been successfully combated in this case. And although the plan of putting water-closets in a vault under the pavement is not one which can be advocated, yet the application of some such appliances as above described will in many cases greatly improve existing closets in such a position.

CHAPTER IX.

STABLES AND OUT-DOOR OFFICES.

Stables—Importance of Ventilation—Harness-room and Coach-house—Cow-houses—Fowl-houses.

All the essential parts of a house and its domestic offices have now been noticed. It remains to describe the accessories not forming part of the house proper, but still being part of the establishment. The first of these is the stables. Here, again, an almost unlimited diversity of size, accommodation, and arrangement presents itself. The main principles are, however, the same in all, whether it be a two-stall stable with chaise-house, or the extensive array of stalls, loose-boxes, and carriage-houses, with other appurtenances proper to a large establishment.

"It has not yet been ascertained how much fresh air a horse requires to keep him in health. Such an inquiry, although of great value when warmth has to be combined with ventilation, is of little importance as applied to stables, because the horse is not an exotic animal requiring artificial warmth. He is taken from a perfectly open-air life, with its vicissitudes of weather and temperature, to be confined, more or less, in a stable, for purposes quite apart from his health. The real question at issue is, indeed, how to subject the horse to the captivity he has to undergo in serving man, without injuring him in his health and strength.

"It is only by keeping this object steadily in view that we can arrive at a thorough understanding of the condition required in stable ventilation. Although all animals have a certain power of adapting themselves to the conditions in which they happen to be placed, it must be evident that the example of nature should be followed as far as possible, and that the natural conditions she has provided should be taken as the model to be aimed at in the change.

"Animal life is most perfectly developed, and its functions are most perfectly performed under the conditions of free diffusion of the atmosphere, including absence of stagnation, abundance of light, absence of nuisance, and sufficient space to live in.

"These are the conditions (besides, of course, food and drink) which nature has bestowed upon the horse.

"Good stable ventilation includes these conditions, because if the stable is filthy, or the ground saturated with putrid urine, it must be obvious that no amount of fresh air passing through the stable will keep it sweet or wholesome. Any amount of fresh air coming in will immediately be tainted by filth which ought not to be there.

"Again, if a stable be ever so clean or well-drained it will never be well-ventilated without perfect freedom of movement of air through every part of it, together with free ingress and egress of air, so provided as to prevent hurtful blasts falling on the horses."* This supply of air must be accompanied by other conditions, such as ample light, absence of noisome exhalations, and plenty of space. No stable should be more than one storey high, the roof should be open, and a con-

* Report of the Barrack and Hospital Commission on the Ventilation of Cavalry Stables, 1864.

tinuous ventilator should be formed on the ridge or apex of the roof. This ventilator should be permanently open. The louvre-boards at the sides will prevent the rain from driving in. Additional ventilation should also be provided by a continuous course of air-bricks in each wall immediately under the eaves. At the head of each stall an aperture of this form (Fig. 30a) should be made. A curved drain-

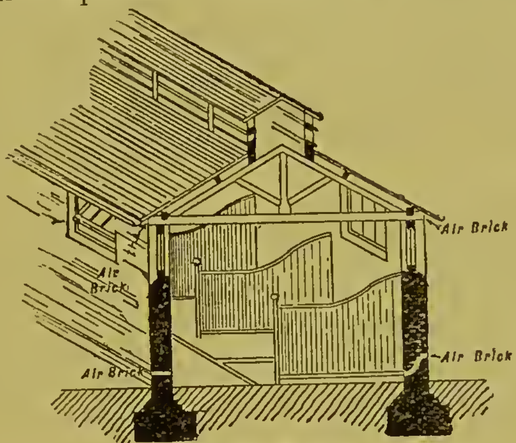


Fig. 30.—Stable.

Fig. 30a.—Ventilating Aperture.

pipe built into the wall serves the purpose admirably, and the apertures may be protected by wire gauze. The object of this opening is to supply fresh air at the floor-level, where the air is necessarily the most impure, by reason of the evaporation constantly going on from the paving. The air which a horse breathes when lying down will by this means be considerably purified.

A stable should be lighted by windows on its opposite sides. Those over the heads of the stalls should have their sills placed not less than five feet six inches from the floor-level, and should be low and wide in form. The windows in the opposite wall may be lower, but the sills should not be less than four feet from the floor. The best form of sash for a stable is the louvre (Fig. 31).

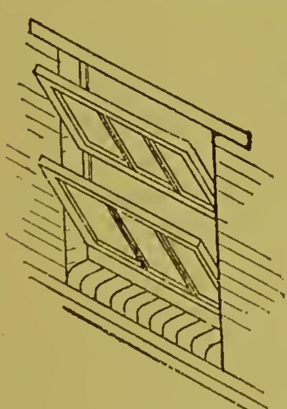


Fig. 31.—Stable Window.

The floor and walls should be of the most impervious nature procurable. The best material for the floor is one of the various kinds of terro-metallic bricks made in Staffordshire (shown in Fig. 32), which contain from seven to ten per cent. of oxide of iron. They are exceedingly hard and impervious, and being chamfered, and of a rough surface, they afford a safe foothold for horses. A patent brick is made from the clay of the Yorkshire coal measures, which is channelled in one direction only, the advantage of this being that by avoiding the transverse channels there is less opportunity for the accumulation of dirt. It is most important to avoid a smooth, slippery surface. For the walls, either glazed tiles or bricks are the most suitable materials. The colour should be a neutral grey or green; white is the worst possible tint for the inside of a stable, as it dazzles the horses, and sometimes even accelerates blindness.

Fig. 32.—Stable Floor.

The angles of the door-openings and the sills of the windows should be of the

same material as the paving-bricks, only with the angles rounded off so as to present no sharp corners that might injure the horse.

The stall divisions must necessarily be of wood. The lower edge of the stall boarding is inserted into a grooved rail which may be either of iron or wood. Of whatever material it is formed it should be kept about two inches clear of the paving, to allow the air to circulate freely all over the stable, and to avoid angles. Care should, however, be taken that the space does not exceed two inches, as a greater space than this would almost certainly lead to accidents by horses getting their feet wedged beneath the rail. Instances of this kind have been known to result in broken legs.

The space usually allotted to a stall is six feet in width and nine feet in length from heel-post to wall. For large horses the width may be increased to six feet six inches. It is unadvisable to exceed this width, as with very wide stalls horses are apt to turn round and foul their feeding-troughs. The minimum cubic space per horse is 1,200 feet. The dimensions recommended by the Barrack and Hospital Commission, as sufficient under proper conditions of ventilation, are 100 superficial feet and 1,600 cubic feet per horse.

Loose-boxes have often to be constructed both in large and small stables. They are sometimes only two stalls thrown together; in all large establishments a separate loose-box or two, entirely detached from the other stables, should be provided, wherein a sick horse could be isolated.

Stable fittings are usually of iron, with the mangers and troughs enamelled inside. These as well as the fittings necessary for the harness, saddles, &c., vary in form and construction according to the different tastes and fancies of owners or their grooms.

Stable doors should be four feet wide and seven feet six inches high, inside the door-frame.

The drainage of the stable should be entirely on the surface. Open channels of wrought iron and without covers are the best for the purpose. The channel should be taken up the centre of the stall to the wall, and should fall to another channel running the whole length of the stable at the back of the stalls. One or more similar channels serve to conduct the liquid manure to an open trapped gully in the yard. Thus all danger from contact with the sewer is kept entirely outside the stable.

In all stables a harness-room should be provided. It should have a small grate, and sometimes it is desirable to fix a small cooking-stove, at which the men can cook their meals. The harness-room is usually boarded all round. There should be a door to the exterior as well as one to the stable.

The coach-house must before all things be absolutely dry. Nothing is more destructive to carriages than damp. The floor should be on an impervious foundation, and the surface may either be asphalte or cement. Broad strips of hard stone should be arranged at the proper distances to serve as tracks for the wheels. The walls may be of glazed bricks or may be plastered. It will frequently be found convenient to form the hay-loft over the coach-house. In this case the floor of the loft should be ploughed and tongued to prevent the passage of dust.

Proper ventilation should be contrived by means of air-bricks, but the ingress of dust and dirt should be prevented as far as possible. In arranging the doors care

should be taken that the hinges do not project when the doors are open, and that a clear space of eight feet is left for the carriages to enter. Less than eight feet will, it is true, admit any ordinary carriage, but some margin must always be allowed for carelessness in backing a carriage in. A paved washing-place is generally formed in front of the coach-house, and it may conveniently be covered over with a light iron or wood glazed roof; the glass should be arranged with interstices at intervals so as not to impede the circulation of air. A properly-trapped gully grating should be placed in the centre of the washing-space, to carry off the water. A supply-pipe with a tap must be fixed in some convenient place close to the washing-place.

The dung should be placed in some convenient spot away from all doors and windows, and should not be placed in pits sunk below the level of the surface in London mews or places where it is only waiting removal. It should then be placed in iron cages, through which the air can blow. When kept for the purpose of manure until it decomposes, the receptacle should be lined with cement, or some other impervious substance. Where such an arrangement is practicable, a separate yard may be provided for the reception of the manure, where it can be turned over and allowed to decompose gradually until it is in a fit condition for use in the garden.

A plentiful water-supply must be provided for stable use. For washing purposes a large soft-water tank would be valuable.

Sleeping-rooms for grooms and others have commonly to be provided, even in small stables. These again should never be over the stables. In large establishments accommodation will have to be provided for married servants and their families, and for unmarried grooms, stablemen, &c. For the unmarried men a well-ventilated dormitory, divided into cubicles by wooden partitions, and a common mess-room, will be a convenient arrangement.

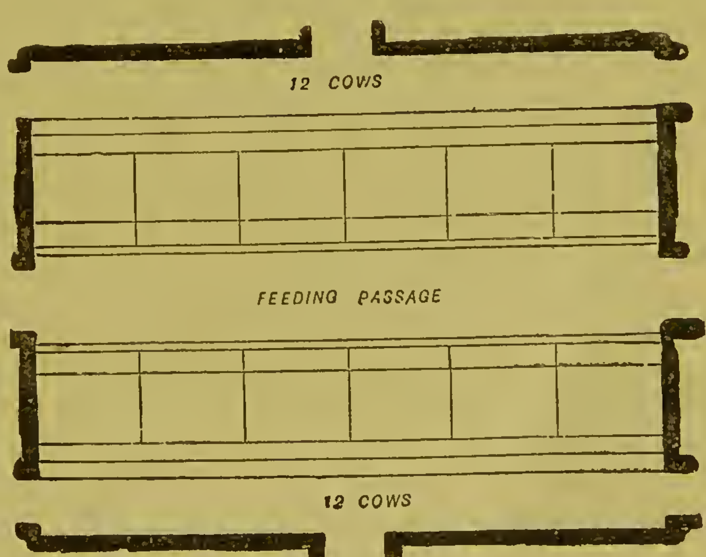


Fig. 33.—Cow-house.

Though it is not within the scope of this work to enter minutely into the wide and ever-varying subject of farm-buildings, yet, inasmuch as, in many country houses, and of course in most farmhouses, the farm-buildings are in close proximity to the dwelling-house, some mention of these seems necessary to the present subject.

The most important of these buildings is the cow-house. Cows are somewhat differently lodged from horses. The best form for a cow-house is that shown in Fig. 33. A central passage with wide doors at each end divides the cow-house into two parts, and the cows stand facing the passage. The feeding-troughs are fixed along each side of the passage, and above the troughs the whole space is open.

The same conditions as to imperviousness of floor and walls apply equally to cow houses and stables, and the same system of drainage is applicable to both—one or two separate divisions should be arranged for cows with young calves, and special attention should be paid to the drainage and ventilation of them. Cows after calving are in a febrile and delicate condition, and need to be carefully protected from injurious exhalations.

Where a large number of cows is kept, the dairy will be an office of some importance. If it is placed among the farm-buildings care must be taken to keep it apart from anything likely to be a nuisance, or to give off unwholesome exhalations. The dairy must be cool and well ventilated, but provided with sufficient protection from extremes of cold and heat. Tiles, glazed bricks, or marble, are suitable materials for the walls of a dairy. The floor may be of brick, unglazed tiles, stone, slate, or marble. The slabs or shelves of either slate or marble. It will be obvious that there is ample opportunity here for an unlimited display of decorative taste. A room must be provided adjoining the dairy for washing the various vessels employed. This room must not communicate directly with the dairy. It should contain a hot-water copper for scalding the vessels.

Special attention must be paid to the water-supply for the dairy and the cow-house. In particular, a proper tank, with pure water laid on to it, must be provided for the cows, and on no account must they be allowed to drink at a pond which is liable to be fouled in any way by drainage.

Pigs will invariably have to be accommodated wherever there are cows. The piggeries should be constructed of brick, with slated or tiled roofs, and brick or stone walls to the enclosures. The roof should be raised above the top of the walls on short pieces of timber at intervals of twelve or fourteen inches, to provide a current of air across the sty. The floors should be properly paved with impervious bricks or asphalte, and the drainage should be as perfect as possible. Pigs, though not the cleanest of animals, need not necessarily be kept in the state of filth they frequently are, and will thrive better when kept clean.

The other appurtenances of a small farmyard will be a barn, poultry-house, cart shed, and stable for one or two cart-horses, and possibly a sheep-house for sheltering sheep in severe winter weather.

Of the last-mentioned appurtenances, the fowl-house is the only one which calls for special comment here. It does not solely pertain to houses to which farm-buildings are attached, but will be found in the garden of a country labourer and the back yard of a London artisan, and frequently under the most offensive and unhealthy conditions.

"A rough enclosed shed is called the fowl-house; it is generally most properly named, for anything more foul and offensive it is scarcely possible to find. Two or three old ash-poles have been nailed across haphazard, generally most ingeniously arranged, that the droppings of each row of fowls shall fall on the backs of those below them; a row of dilapidated boxes called nests, oftentimes with the hay and straw of the previous year or more left in, with old shells of the former hatchings, very often the remains of a smashed rotten egg adhering to the straw; the hay or straw full of vermin. When a hen, despite of all these horrors, has set herself, the nest is so exposed that half the other hens desirous of laying fight the

occupant, and incessantly disturb her in her process of incubation. Is it then to be wondered at that hens *steal* their nests, as it is called, and wander into the hedges and rick-yards and set themselves, and become a prey to foxes, polecats, or weasels? No provision is made for giving poultry clean water, and the result is the fowls drink the sewage-water of drains, and especially the drainage-water from the stables and manure-heaps, than which nothing can be more injurious, especially to young chickens, producing "gapes" and diarrhœa, with other kindred diseases. As to feeding, I might say *starving* is the rule, and the bulk of the poultry may get their living as they can. The only chance for our poor feathered friends under these circumstances is for them to roost in the cart-hovel and implement-shed, where they probably have the satisfaction of breathing pure air, and have some slight revenge for the neglect shown by contriving to smother the implements beneath them with the produce of the rick-yards and pigsties." *

Such an arrangement of fowl-houses as that above described cannot fail to have injurious effects upon the health of the persons frequenting it; and though elaborate and costly houses and appliances are not to be recommended, yet the arrangement and construction ought certainly to be more in accordance with proper sanitary conditions. The perches, which can readily be made of fir poles sawn down the centre, and placed with the round sides uppermost, should be fixed on a sloping frame, so that the fowls cannot by any possibility roost one immediately over the other. The place for sitting hens should be in a separate compartment, where each bird can sit in undisturbed comfort. The nests should be placed on the ground in the roosting-house, and properly supplied with fresh hay or straw. The floor under the perches should be regularly cleaned once a week, and fresh sand or dry earth laid down. It should be remembered that the excrement of fowls is a manure of considerable value. Finally, clean water should be supplied in iron troughs.

* Notes on Poultry by J. K. Fowler in the "Guide to the International Exhibition of the Royal Agricultural Society, 1879.

CHAPTER X.

INTERIOR CONSTRUCTION.—TIMBER-WORK.

Various Kinds of Timber—Pine Woods—Hard Woods—Roofs and their Construction—Floors and Joists—Sound-proof Floors—Partitions—Doors—Windows and Sashes—Skylights—Shutters—Stairs and Staircases.

Before describing in detail the several parts of a house which fall under the head of Carpentry, it will be convenient to give a short account of the various kinds of wood used in the construction and fittings of the interior.

All timbers used in building belong to the class known by botanists as *Exogens*, or trees which increase by outward growth. The cross section of an exogenous tree exhibits a number of concentric rings round the pith, and lines of varying thickness in different woods radiating from the pith to the bark, and also from the bark towards the centre. The concentric rings are called annual rings, and the radiating lines the medullary rays ("the silver grain" of the carpenter). Without going minutely into the construction of cellular and vascular tissue, it will be sufficient for the present purpose to describe briefly the mode in which the annual growth of a tree of the kinds about to be considered is attained. The principal part of the liquid food required for its nourishment by a tree is absorbed by the roots, and becomes part of the sap. The sap ascends through the stem and branches, and so reaches the leaves, where the superfluous moisture is exhaled, and carbon is absorbed. The sap, very materially altered, descends again, but not by the way it came; its downward journey being by way of the under side of the bark, where it deposits a layer of new wood. This process is, as a rule, performed once in every year; hence the term annual rings.

The inner layers, or "heart-wood," are the hardest parts of the stem, and with the growth of the tree increase in hardness and density. The outer layers, through which mainly the sap ascends, are called "sap-wood," and are softer, and usually different in colour from the heart-wood. It is, as Mr. Hurst remarks, reasonable to suppose that the sap-wood, containing, as it does, vegetable matter, which is eventually to be expended in the nourishment and formation of leaves and buds, would be more prone to decay than the inner layers, up which the sap does not ascend. One of the most important points in selecting timber is to be able to recognise and reject sap-wood. Timber that has by some means or other become stained whilst lying in the water at the docks presents a somewhat similar appearance to sap-wood. It will be found, however, that whilst these water-stains penetrate irregularly through several rings, the sap-wood is almost invariably exactly co-terminous with one of the annual rings.

Closeness and straightness of grain, a bright and glossy surface, and uniform colour are the most prominent characteristics of good timber.

The preceding remarks apply equally to all kinds of timber used in building. It remains now to describe in more detail the various kinds of timber, and for

this purpose it will be convenient to adopt the classification made by Professor Rankine and Mr. Hurst.*

Omitting details, we find timbers divided into two main groups. A. Pine-wood, or coniferous timber (Coniferæ: Nat. Ord.)—pine, fir, larch, cedar, &c. B. Hard wood, or non-coniferous timber—oak, beech, ash, elm, mahogany, walnut, &c.

Of these two classes, the first, including as it does all timber known to the carpenter under the general terms of deal or fir, is by far the more important to the subject under consideration.

The special characteristics of fir timber are thus described by Professor Rankine:—"Fir-wood, or coniferous timber, in most cases contains turpentine. It is distinguished by straightness in the fibre and regularity in the figure of the trees: qualities favourable to its use in carpentry, especially where long pieces are required to bear either a direct pull or a transverse load, or for purposes of planking. At the same time, the lateral adhesion of the fibres is small, so that it is much more easily shorn and split along the grain than hard wood, and is therefore less fitted to resist thrust or shearing stress, or any kind of stress that does not act along the fibres. Even the toughest kinds of fir-wood are easily wrought."†

The most valuable tree of the coniferous class is the Northern Pine (*Pinus sylvestris*), or Scotch Fir. The best fir timber imported into this country is grown in Russia and Prussia, and takes its name from the ports whence it is shipped. Architects usually specify that the fir timber shall be Riga, Christiania, Dantzic, or Memel. Of these, Christiania yellow deals are considered to be the best. Fir timber is also imported in large quantities from Norway and Sweden, but of a much inferior quality. Exception must, however, be made in favour of the best class of Gefle deals. The inferior qualities of Gefle deals are like the majority of Swedish timber, coarse, full of knots, and sappy.

Pitch Pine (*Pinus rigida*) is often exceedingly handsome in the grain, and has been very largely used for ornamental work on that account. It is very full of resinous matter, which conduces materially to its durability, but makes it difficult to work. Workmen dislike it because the resin clogs their tools.

White Fir, or Spruce (*Abies excelsa*), commonly known as White Deal. This is a soft wood, and easily worked, but very inferior in strength to either of the foregoing woods. It is only fit for the inferior kinds of joinery, table and dresser tops, and packing-cases.

American Red and Yellow Pine are woods of much inferior quality to Baltic timber. The former is almost entirely used for veneering. The latter is an excellent wood for joiners' work, but appears not to be well adapted for the English climate. It is, moreover, subject to dry rot.

Several varieties of spruce timber are imported from America, and resemble in appearance and quality that from the Baltic.

The Larch (*Larix europea*) is a remarkably tough and durable wood. It is a valuable wood for palings and fences, also for stairs and floors which have to withstand very much wear.

* Tredgold's "Carpentry," edited by J. T. Hurst, 1875.

† Rankine: "Civil Engineering," p. 440.

A few other varieties of the coniferous tribe are occasionally used for joiners' work, such as the Cedar, Cypress, Oregon Pine, and others. They do not, however, call for any particular description here.

The second division, or timber of the hard wood kind, is thus described by Professor Rankine :—"In hard wood, or non-coniferous timber, there is no turpentine. The degree of distinctness with which the structure is seen, whether as regards medullary rays or annual rings, depends upon the degree of texture of different parts of the wood. Such difference tends to produce unequal shrinkage in drying, and consequently those kinds of timber in which the medullary rays and the annual rings are distinctly marked are more likely to warp than those in which the texture is more uniform. At the same time, the former kinds of timber are, on the whole, the more flexible, and in many cases are very tough and strong, which qualities make them suitable for structures that have to bear shocks."*

First in point of utility among the hard-wood timbers comes Oak. A close grain, with small pores, a light-brown colour, and glossy surface, are characteristics of sound oak timber. A reddish colour and large open pores are signs of decay. In properly-ventilated positions oak will last for an almost indefinite period. Gwilt affirms that it has been ascertained to have lasted for nearly a thousand years. Most of the elaborate and beautiful roofs of the fourteenth and fifteenth centuries, of which those of Westminster Hall, Eltham Palace, and Hampton Court Palace are well-known examples, are of English oak. It is particularly useful for window-sills, half-timber framing, gate-posts, and in exposed situations. In the larger kinds of houses it is used for joiners' work, such as panelling, doors, stairs, and floors. Pollard oak is, from its rich and varied grain, very useful as a decorative wood. The best quality of oak is that grown in this country, and the pre-eminence is usually allowed to oak of Sussex growth. Several different kinds of oak are imported from abroad; of these the wood known as wainscot is the most important. It is a softer wood and more easily worked than English oak, and is particularly suitable for purposes of joinery.

Teak—sometimes called Indian oak—is a darker and heavier wood than oak. It is also straighter and more uniform in the grain, and stronger than oak. The best quality is that from Moulmein. It is largely employed in ship-building and for railway carriages, but the cost prevents its general adoption in building. Its use for treads of staircases is, however, becoming more frequent.

Elm was formerly much used for joists and floor-boards, but has fallen into disuse on account of its liability to decay. It is, however, useful for the curbs of mangers, and for kicking-boards in stables, and also for piles. Elm has also in a very remarkable degree the property of durability under water. Several of the piles under old London Bridge, which had been in position some six or seven centuries, were found, when the new bridge was being built, to be perfectly sound (*vide* Tredgold by Hurst, p. 357). A more remarkable instance of the durability of timber under water is that of the piles of the bridge built by the Emperor Trajan across the Danube. One of these piles on being taken up was found to be petrified to the depth of three-quarters of an inch; the rest of the wood was in its natural state, though it had been submerged more than 1,600 years.

* Rankine: "Civil Engineering," p. 440.

Mahogany is of two kinds: Honduras and Spanish. Honduras mahogany comes from Central America, and is lighter in colour and coarser in texture than Spanish. Cuba, or Spanish mahogany, comes from the island of Cuba, and is distinguished by the extreme beauty of the figure or grain. In building, mahogany is used for handrails, doors, sashes, and other interior work. It is not suitable for constructive joinery, nor for exterior work of an exposed nature.

Walnut is a useful wood for panelling and decorative work. The best kind is that imported from America.

The foregoing are the woods most generally in request for constructive and decorative purposes; some other woods there are which are occasionally used, as, for instance, maple, satin-wood, ebony, and box-wood. These are, however, useful solely for their decorative qualities, and do not require any further description here.

The various marks, or brands, which are seen on the ends of most kinds of timber refer sometimes to the quality of the timber, sometimes merely to the cubical contents. These marks are liable to be changed from year to year: being, in fact, as a rule, the private marks of the merchant who exports the timber. Except to those practically acquainted with the trade and its customs, these marks are really no guide in the selection of timber.

Certain precautions are necessary to protect even the best possible quality of timber from rot and decay after it is placed in the position it is intended to occupy. Damp walls, want of air, immediate contact with mortar, damp earth, or vegetable mould, but worst of all, alternations of damp and dryness, or moisture attended by heat, all tend sooner or later to produce decay in some form or other. To counteract this, it is necessary to adopt the following precautions:—The ends of all timbers resting on walls should have a clear space of air round them, with provision for ventilation by means of perforated bricks. The larger timbers, girders, tie-beams, and the like, should rest on stone templates, and the smaller joists for floors and ceilings on hoop-iron bond, laid on a course of bricks in cement. This latter arrangement is an excellent substitute for the old system of wall plates, which are so liable to decay. Cradles of burnt fire-clay are also made for the purpose of receiving the ends of timbers, and if proper provision be made for ventilation, are excellent things for the purpose. The cavity under the joists of the lowest floor should be deep enough to allow of spaces being left in the sleeper walls to form, in conjunction with the air-bricks in the external walls, sufficient currents of air to ventilate the joists. The ends of oak posts which are to be driven into the ground should be either charred or treated with some such process as that of Sir William Burnett, which consists of steeping the wood in a solution of one pound of chloride of zinc to four gallons of water. It is, however, of little use to char any but well-seasoned timber. Charring applied to green timber only closes up the moisture and sap, and prevents evaporation. Painted floor-cloths are particularly injurious to wood floors, by confining the moisture, and preventing the access of air.

Under certain conditions it is absolutely necessary to adopt some method to preserve timber from decay, and the attacks of insects or boring mollusca. In Holland, for instance, where whole towns are built on wood piles, it is a matter of vital importance to secure the wood from the attacks of the "teredo navalis," or ship worm. But circumstances of this nature will rarely, if ever, occur in this country, and the old rule of "prevention is better than cure" holds good in this

case. Well-seasoned timber, properly ventilated, is what is needed. Having secured this, we need be at no pains to adopt any preventive process.

The various applications of timber to the different parts of the interior of the house will now be considered.

Roofs.—Several different forms of roof are used in domestic building; those most frequently employed will be found in the following list:—

Fig. 34.—"Lean-to," as its name implies, has only one slope, which leans against a vertical wall.

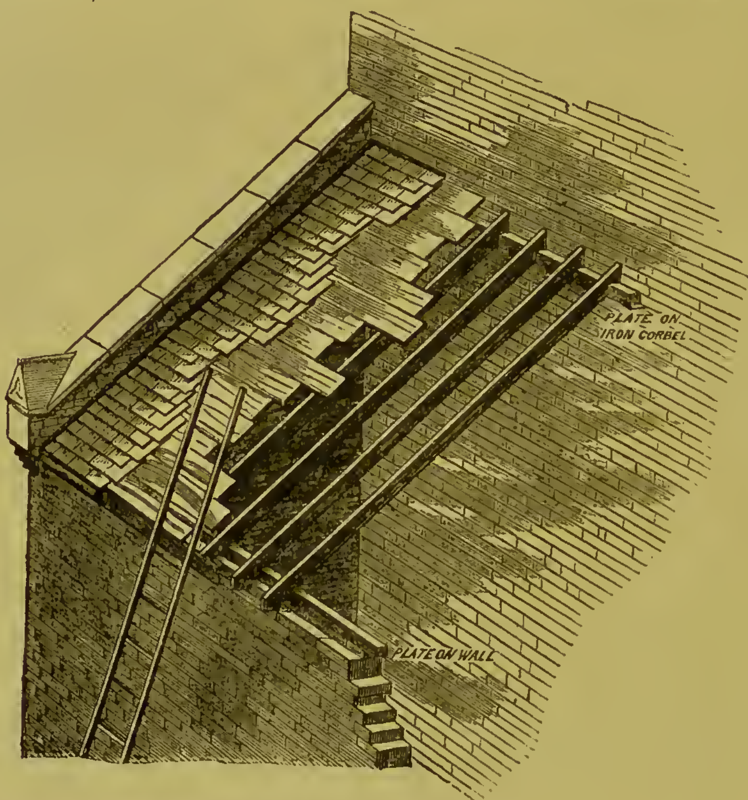


Fig. 34.—Lean-to Roof.

Fig. 35.—"M," or "ridge-and-furrow" roof, is formed by two triangular roofs side by side.

Fig. 36.—"V" roof, formed by two slopes or lean-to roofs meeting in a gutter, the slopes resting against the party walls.

Fig. 37.—"Curb," or "Mansard" roof, in which the apex of a steep-pitched triangular roof is cut off and replaced with a triangle of much flatter pitch.

The above are the forms of roofs most usually employed in dwelling-nouses; there are, besides, flat roofs and roofs of ogee shape. These latter are rarely employed, and only for roofs of turrets.

The simplest form of roof is that known as a "couple" roof (Fig. 38). This consists only of two rafters fixed at the required pitch or inclination, and fastened at the feet to a plate embedded on the top of the wall, while their heads are either halved and pinned together or nailed to a ridge-board. The obvious tendency of such a roof as this is to spread at the foot and thrust out the walls. The remedy for this is to be found in fixing across, from rafter to rafter, a light beam, called a "collar." This

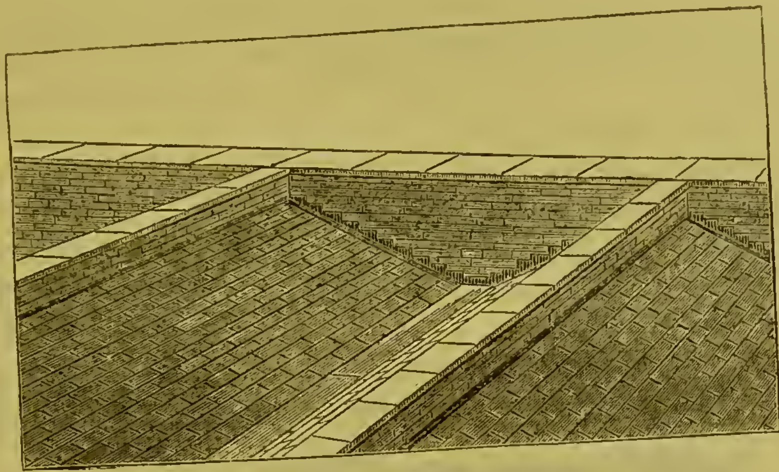


Fig. 36.—"V" Roof.

Fig. 35.—Ridge and Furrow Roof.

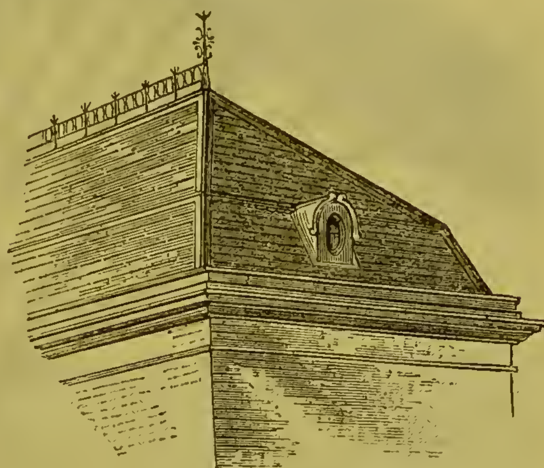


Fig. 37.—Mansard Roof.

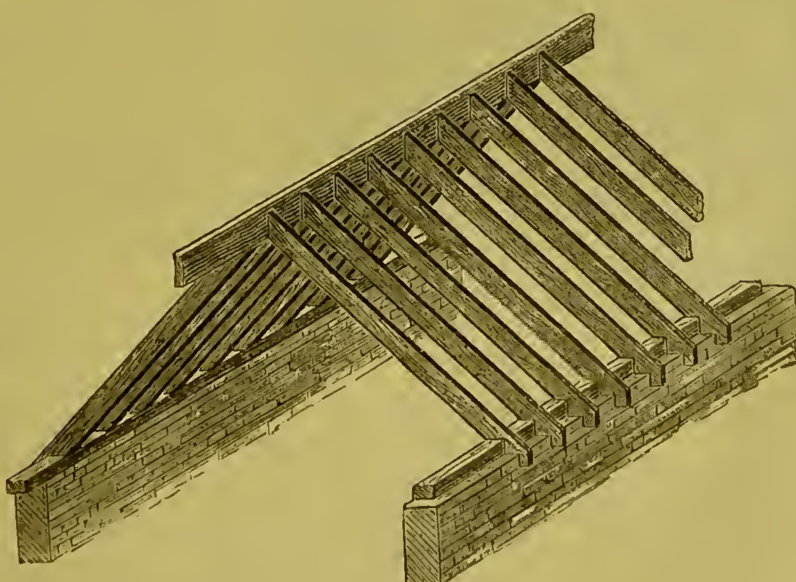


Fig. 38.—Couple Roof.

beam serves as a tie to hold the rafters together, and prevent them from thrusting out the walls. For roofs of a span of ten to fifteen feet this is all that is needed. In many instances the collar may conveniently be made to serve the purpose of a ceiling-joist also.

For roofs of from fifteen to twenty feet span a tie-beam should be used. This is a beam placed horizontally from wall to wall, the rafters being fixed thereto, and the beam being also notched down on to the plate: the whole is well tied together, and any tendency to thrust out the walls is counteracted. When the extra weight of a ceiling is added, it is sometimes a wise precaution to fix a slight rod from the ridge to the centre of the tie, to give support in the weakest part.

Where a greater span than twenty feet has to be covered, it becomes necessary to provide additional support both to the rafters and the tie-beam. This is done by the aid of a "truss," the simplest form of which is that called a "king-post truss" (Fig. 39). By means of the principals, C C, and the king-post, B, the beam A is supported or trussed at its weakest point, the centre. The principals are also supported in their turn by struts, D D, from the king-post. The feet of the common rafters are notched on to the pole-plates, H H, while additional support is afforded in the centre by purlins, E E, which run from truss to truss. The king-post is continued up past the principals to give support to the ridge-piece, G, against which the heads of the common rafters abut. For all ordinary domestic purposes such a roof as this will be found sufficient.

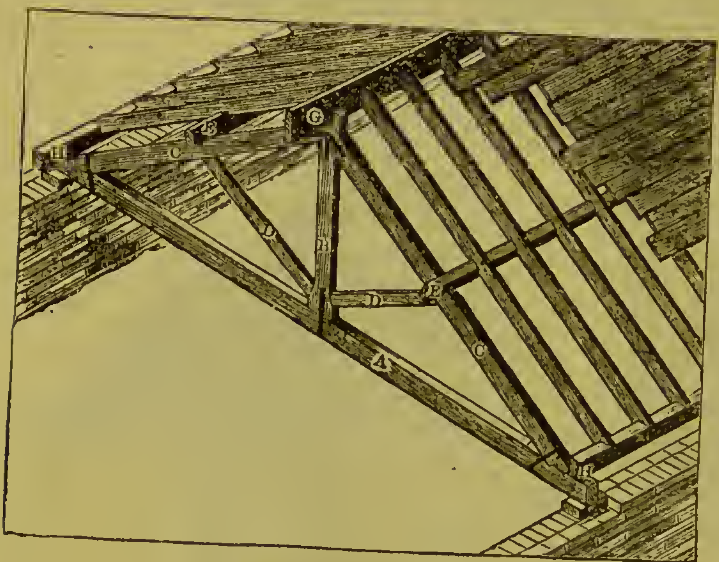


Fig. 39.—King-post Truss.

For spans of thirty feet and upwards, trusses of somewhat more complicated construction are required. As, however, such spans are rarely used in ordinary domestic houses, and as, moreover, the principle of framing and support is the same, whatever span is required to be covered, it will not be necessary to enlarge further on this subject.

Where the roof is intended to be shown, as in the case of a large hall of a mansion, in billiard-rooms, or in other positions, various forms of a more or less ornamental nature are used. Among these may be mentioned curved collar-beams and braces, turned tie-beams and king-posts, and roofs of the hammer-beam kind. These last—a well-known example of which is the roof over Westminster Hall—are weak in construction, and require to be supported externally by massive buttresses.

Floors.—The simplest form of floor consists of a row of beams, or "joists," varying in thickness and depth with the width or "bearing" between the walls on which they are supported. To the upper sides of these joists the floor-boarding is

nailed, and to the under side the laths which carry the ceiling are affixed. These joists should not be placed at a greater distance than fifteen inches from centre to centre. Where the distance between the supporting walls is as much as fifteen feet, it is usual to put girders of either wood or iron at intervals, and to support the

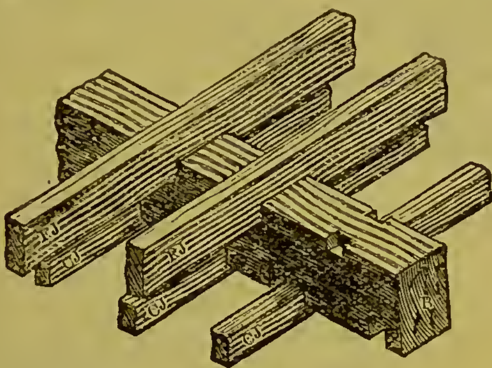


Fig. 40.—Double floor Joists.

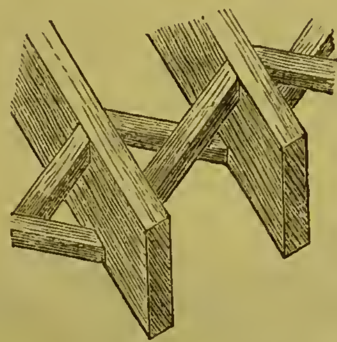


Fig. 41.—Herring-bone Strutting.

joists on the girders. A better kind of floor is what is known as a "double floor." In this floor there are two sets of joists, the lower set being smaller, and used solely to support the ceiling: hence called "ceiling-joists." The advantages of this kind of floor are that the ceiling, being supported independently of the floor-joists above, is not liable to be jarred by the traffic overhead, and that the connection between the ceiling and floor being broken by the space between the two sets of joists, sound from above is not so audible as where the floor is single. The joists in a double floor are supported on transverse beams, called binders. In the annexed illustration (Fig. 40), B is the binder, F J the floor-joists, and C J the ceiling-joists. The floor of a room in the basement storey, or on the ground-level where there is no basement, is formed with small joists laid on "sleepers"—oak plates, generally four inches square and laid four to five feet apart on dwarf walls. These oak sleepers are, in order to ensure thoroughly-seasoned wood, generally specified to be of ship oak.

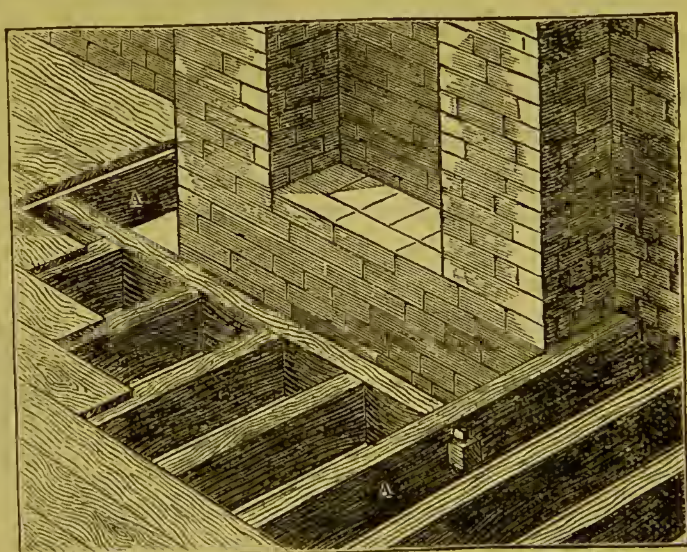


Fig. 42.—Trimming Joist.

Cross pieces of wood are frequently fixed between the joists thus (Fig. 41), with a view to strengthen and increase the rigidity of the whole floor. This is called "herring-bone strutting." It cannot be said to very greatly assist the bearing-power of the floor, and is too frequently but a feeble adjunct to a feeble floor. A better kind of strutting is that known as "solid strutting." In place of the crossed struts, a solid piece of wood about an inch thick is placed between each joist, and an iron rod

placed alongside it and passed through the whole tier of joists. When the floor has settled down into its place, this rod is bolted up tight.

Where fireplaces and flues occur in the wall on which the ends of joists rest, it is necessary to adopt some plan by which the ends of the joists are kept a sufficient distance from the flue, or chimney-opening. Fig. 42 shows the method of doing this: A A are the two joists, called "trimming-joists," which come on either side of the chimney-breast, or projection for the fireplace; into these, at a sufficient distance—generally 18 inches—from the fireplace, is fixed a short piece, called the trimmer, which gives support to the joists between A A. The trimmer also serves to support the brick arch which is formed to carry the hearth. It is also necessary to "trim" joists in a similar manner where trap-doors occur, and on landings of staircases. Trimmers and the joists into which they are trimmed should always be somewhat thicker than the ordinary joists.

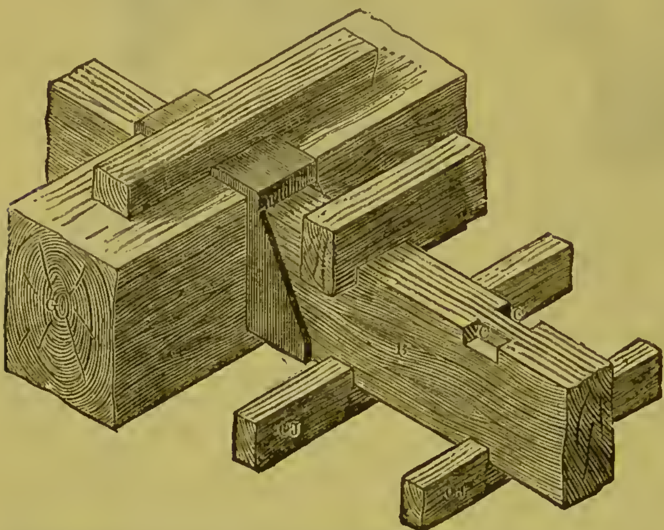


Fig. 43.- Double-frame Floor.

Fig. 43 shows the proper method of constructing a double-framed floor when it is not desired to show the girder below the ceiling-level. G is the girder, B the binder, C C the notches to receive the floor-joists, C J the ceiling-joists. The iron stirrup which holds the binder on either side of the girder obviates the necessity for cutting into the girder and tenoning the binder into it. The girder is thus left intact, and consequently much stronger.

Floor-boarding is of many kinds, varying from the rough boarding for barns and lofts to the most elaborate parquetry. The simplest form of flooring (after the "rough" boarding just mentioned) consists of deal boards 7 inches wide, planed on one side and both edges, and nailed down to the joists as close together as they will go. A floor of this kind is generally laid by a process technically known as folding. The method is as follows:—When the whole of the boards destined for the room are laid down, it is found that two of them incline to each other at an angle, thus (Fig. 44). The carpenter then places a board transversely on the upper edges of these two boards, and jumps on the transverse board until he has forced the two boards into a horizontal position, and thus has the whole floor level. This very primitive process over, he can proceed to nail down his floor. In better kinds of floors an instrument known as a floor-dog is used,

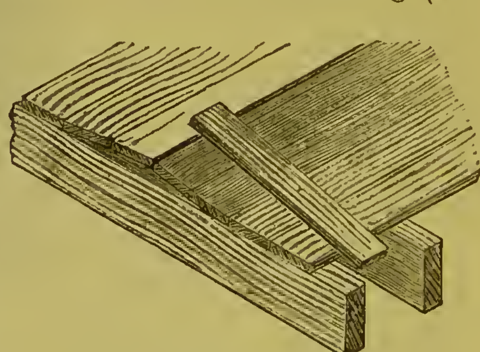


Fig. 44.—Floor-boarding.

by means of which each board is held firmly in its position whilst it is being nailed.

In all floors which are ceiled underneath, means should be taken to prevent dust or particles of any kind from falling between the boards. Any accumulation of organic matter on the upper surface of the plaster is certain to decompose. The ceiling being, moreover, always more or less porous, these particles gradually work their way to the under surface, and produce a stained appearance, which no amount of whitewashing or scraping will remove.

The usual method of preventing this is to form what is called a ploughed and tongued floor. Fig. 45 shows a floor of this kind. Each board is grooved

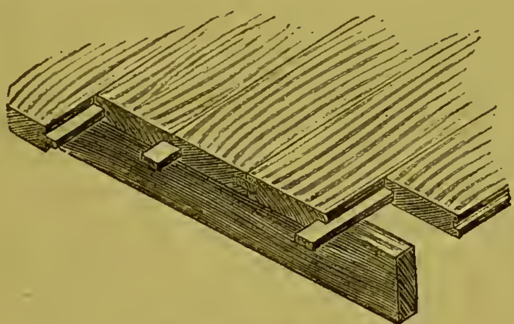


Fig. 45.—Tongued Floor.

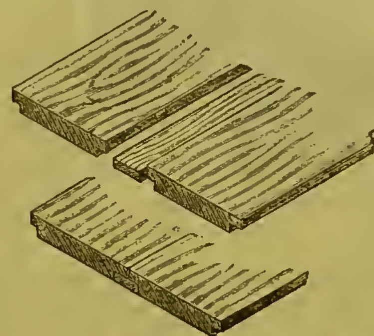


Fig. 46.—Rebate and Fillet.

on each edge, and thin slips, or tongues, of either iron or wood are inserted. If of iron, the tongue should be galvanised. The tongue should be fixed nearer to the lower edge of the board than to the upper, so that as much wear as possible can be had out of the floor before the tongue is exposed. Another method of attaining the same object is what is known as rebating and filleting (Fig. 46). A "rebate" is cut on the lower edge of each board, and a fillet of oak or some other hard wood fixed in the space thus formed. For superior work, a dowelled floor has the advantage of showing no nails on the surface. The boards are pinned together between the joints with oak pins, and nailed obliquely on one edge only (Fig. 47.) Dowelled boards should not be more than 3 inches wide, and not less than 1¼ inches thick when finished.

An upper layer of thin oak boards is sometimes fixed over a rough deal floor, for the sake of appearance, and also in some cases to obtain an almost impervious surface. A floor of this kind, wax-polished and well laid, is much to be commended for the ease with which it can be cleaned, and its non-absorbent nature.

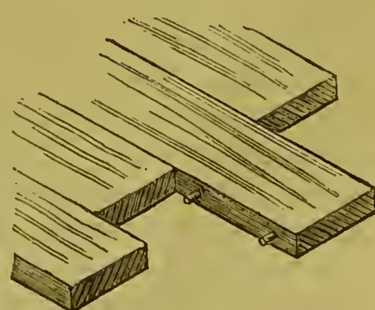


Fig. 47.—Pinned Floor.

The points of contact between the ends of two floor-boards are called heading-joints. These joints should always be arranged to occur over a joist, and contiguous boards should have their heading joints on different joists. This is called "breaking joint." The actual joint is made in different manners. In common floors the boards simply butt up against each other; in better work the heading-joints are splayed as in Fig. 48. Sometimes the heading-joints are grooved and tongued in a similar fashion to the longitudinal joints described above. In very expensive work the "ends

of the boards are cut into a series of sharp, salient, and re-entering notches, whose ridges are parallel to the surface of the floor. These notches fit one another, and form a tight joint. Such joints are sometimes used in oak floors, they are extremely troublesome and expensive to make, and the point nearest the surface of the floor is very liable to break away even in hard wood."*

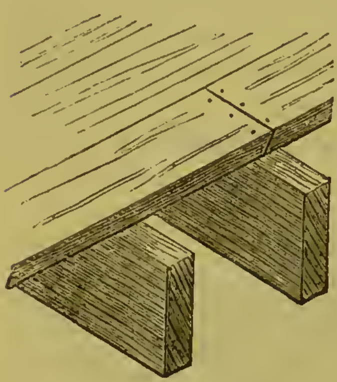


Fig. 48.—Splayed Joint.

The following remarks will be found applicable to all sorts of floors. The joists should always be laid across the narrowest part of the room, and girders and binders should be so arranged as to take a bearing on a solid pier or wall, and not over door or window openings. In cases where a long distance has to be traversed by a joist, and it is supported by one or more girders in the length, it should be made as long as possible. By this means the strength of the joist is greatly increased, as also is its usefulness as a tie to the walls.

Flooring-boards should be cut and prepared, and stacked in the open air, with free ventilation all around, with proper protection from wet, for as long a period as possible before they are required for use. Where such an arrangement is possible, it is well to have the boards laid down in the position they are to occupy for some months before they are finally nailed.

Two other forms of wood floor remain to be noticed. The first, which is a purely decorative addition to an ordinary floor, consists of inlaid pieces of oak and other woods, and is known as parquetry. The patterns are usually prepared in square slabs about $\frac{3}{4}$ inch in thickness, and there is scarcely any limit to the elaboration of design to which this form of floor is susceptible. The second kind of floor is that formed of wood bricks, generally 10 inches long, 3 inches wide, and of thicknesses varying from $\frac{3}{4}$ inch to $1\frac{1}{2}$ inch. These bricks are laid in a mixture of tar and asphalte on a stratum of concrete. This system makes a very durable kind of floor, and the appearance can be varied at a very slight additional cost. Wood brick floors with the end grain upwards are also sometimes used, but are not so easily cleaned, and are very readily stained.

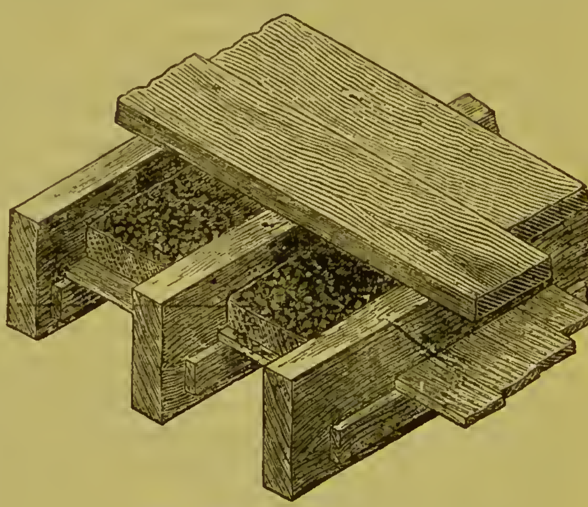


Fig. 49.—Sound-proof Floor.

It is often desirable to prevent the sound from one room being audible in another room immediately below. One method of effecting this is to fix on fillets nailed to the joists a layer of rough boards, and to fill in on the top of these boards a stratum of lime and hair mortar (Fig. 49). Slag felt, a preparation of slag wool, which is a material produced by blowing off waste steam into the slag of iron

* "Notes on Building Construction," Part I., p. 96.

furnaces, is also used for this purpose, and is said to have a remarkable power of deadening sound. In the case of the slag felt the process is as follows:—On the under side of the joists fillets are nailed to wooden blocks one inch thick, and to these fillets the lathing for the plaster ceiling is affixed. The slag wool is then laid on the upper surface of the laths, and is felted by a patent process. It is claimed by the inventor that his process of felting removes entirely the property which the slag wool possesses of emitting sulphuretted hydrogen, and also of reducing in a very remarkable manner the weight of the material. Both of these materials, being fireproof, are to be preferred to sawdust and other combustible materials sometimes used. Another means of attaining the desired end is to nail strips of felt on the upper edges of the joists, under the floor-boards. By this means the connection between the joists and boarding is broken. This arrangement, as Mr. Stevenson* points out, creates some difficulty in fixing the boards, which can be overcome by nailing a lath along the top of the felt.

Partitions.—In order to economise space, the dividing walls between rooms are often formed of wooden framing plastered on each side, the whole thickness of which, including plaster, is six inches as against eleven inches, the thickness of a nine-inch wall when plastered. In forming these partitions it is necessary to guard against settlements, which result, of course, in cracks in the plaster and cornices. To accomplish this, partitions should be suspended in the manner shown in Fig. 50. The ends of the partition are carried on the main walls, and the whole piece of framing forms, in fact, what is known as a "truss." Any settlement occurring in the outer walls, providing they are of equal height, will carry the partition down bodily, and no injury will be done to plaster, ceiling, or cornice.

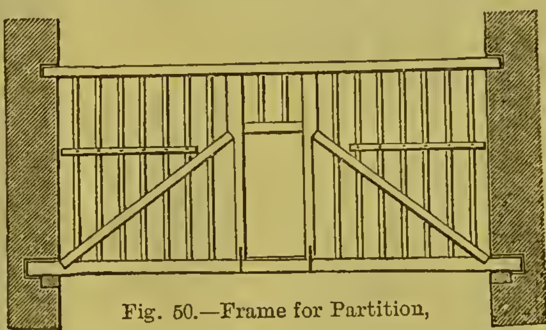


Fig. 50.—Frame for Partition,

Skirting and Dados.—The strip of wood which, of varying height and degrees of moulding, is fixed around the walls of a room immediately above the floor, is called the skirting, and when above this again the walls are panelled to a height of three or four feet or more, the whole is called a dado. Some sort of skirting is always necessary when the walls of a room are plastered, in order to make a neat finish between the plaster and floor-boards. It is, however, far better to form the skirting in cement than in wood. Whichever material is used, the projection and mouldings—except, of course, where elaborate work is a necessity—should be as slight and simple as possible. The most satisfactory form of dado and skirting would be glazed encaustic tiles, with marble mouldings or marble inlay throughout. These are, however, costly materials, and quite out of the question where expense has to be considered. Another method of panelling which can be applied with ease to large surfaces of walls is to cover the walls with thin veneers of wood, applied in the same way as paper-hangings; wooden mouldings can then be affixed to form the panels in any way required. A surface is thus obtained which is durable, cheap, and washable.

Doors.—The simplest form of door is the ordinary four-panel square door,

* "House Architecture."

such as is commonly used for servants' offices, bed-rooms, and the like. The more elaborate forms of doors are really developments of this elementary type of door by the addition of panels, mouldings, and other ornamental features which it is not necessary here to describe. The construction of doors will be readily understood by a reference to Fig. 51. The top rail, middle rail or lock rail, and bottom rail are all tenoned into the styles, whilst the muntings are tenoned in a similar way into the rails. It will be noticed that, besides the mortices in the styles and muntings, there are also vertical grooves, into which the panels are inserted. It will thus be seen that if, in a properly constructed door, the parts should shrink, there is no possibility of daylight showing through the cracks. The middle rail has two tenons, and on the side on which the lock is inserted the tenons are four in number, to allow the lock to be fixed without cutting the tenons. The double tenons are to avoid cutting so large a mortice in the style as a tenon the whole depth of the rail would require. The door is put together with wedges driven in on each side of the tenons. It will perhaps give some idea of the amount of labour involved in making an ordinary four-panel moulded door if it is mentioned that, without counting the wedges, it contains forty-three separate pieces of wood. Doors ought to be framed together, and left to season for as long a time as possible, before they are required to be fixed. When the time for fixing comes, they should be taken to pieces, the mortices carefully cleaned out, glued, put together, and the wedges driven in, and the whole cleaned off.

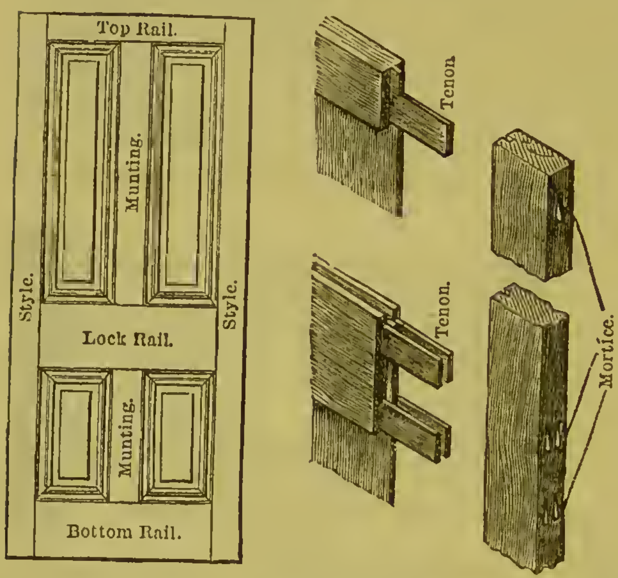


Fig. 51.—Construction of Doors.

In setting out the parts of a door, the centre of the middle or lock rail should be kept at a height of three feet from the floor-level, this being the most convenient height for the handle.

When the upper part of a door is to be filled with plate glass, the glass should be fixed in with beads fastened with screws in brass slots. To counteract the effects of sudden jars, the glass should be bedded in wash-leather.

Folding doors are often required, especially in houses of the suburban villa class. They seldom work well, the fault usually lying with the hinges, which are, as a rule, too weak to do the work required of them. Another mode of throwing two rooms into one is by sliding-doors. They are hung on wheels working overhead on hard-wood runners. Doors of this kind have been largely used, and with satisfactory results, in the numerous Board Schools built in the last few years.

Doors and gates for stables and outhouses are framed on a somewhat different principle. Instead of the skeleton framing being filled in with panels, vertical boards with a V-shaped joint are nailed outside the framing.

(See Fig. 52.) A door of this kind is called a framed and braced door. Stable doors are usually divided horizontally about midway in their height. When this is done, a thin piece of iron should be fixed on the inside edge of the top rail of the lower door, and the joint between the two doors should be splayed.

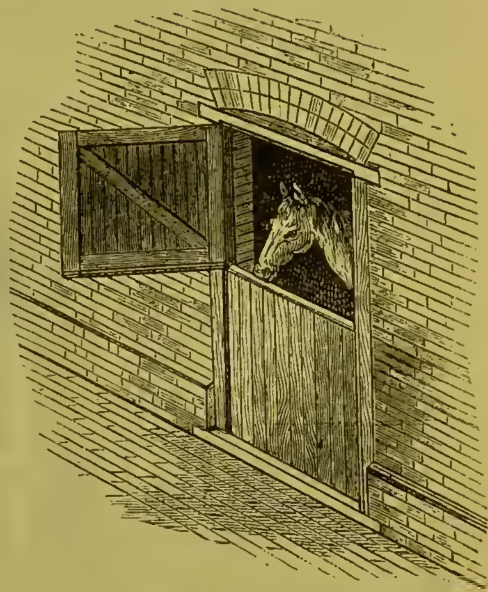


Fig. 52.—Stable Door.

The proper width for stable doors is four feet, and for coach-house doors (for ordinary carriages) eight feet.

The most suitable kind of door for outhouses is what is known as a ledged door (Fig. 53). This is formed of vertical boards held together on the inside by horizontal rails or ledges, usually $1\frac{1}{2}$ inches thick. All external doors ought to have some kind of weather-board at the lower edge, to prevent the driving rain from penetrating under the bottom of the door.

The sizes of doors must necessarily vary with the position, dimensions, and use of the rooms to which they belong. As a general rule, no single door should be of a less width than 2 feet 6 inches, and no double door should be less than 2 feet each. For bed-rooms and rooms of minor importance 2 feet 10 inches by 6 feet 10 inches is a convenient size. Sitting-room doors should be not less than 3 feet by 7 feet. For large and important rooms a width of 3 feet 6 inches is not too much, but no single door should be wider than this.

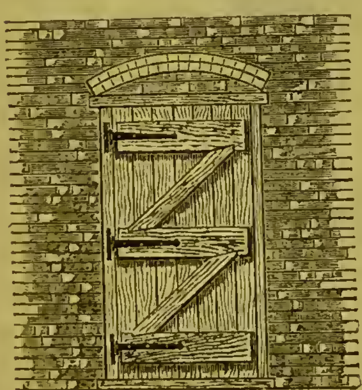


Fig. 53.—Outhouse Door.

The position of the door in a room is, of course, governed by various circumstances, as the position of windows, fireplace, and also the use to which the room is to be applied. It may, however, be taken as an invariable rule that a door should always open in such a way that when open the room is screened. It should not be so near the fireplace as to interfere with the comfort of people sitting round the fire; and it will also be found a good plan to place the door, if possible, opposite a window.

There are various ways of fixing doors. In lath and plaster partitions the usual way is to nail strips of wood, called linings, to the post. (See Fig. 54.) These linings are splayed to receive the plaster, and the joint between lining and plaster is covered by a moulding, called the architrave. On the inside of the opening another lining, called the jamb-lining, is fixed, and to this the door is hung. A more solid arrangement is to bring the post A


Fig. 54.

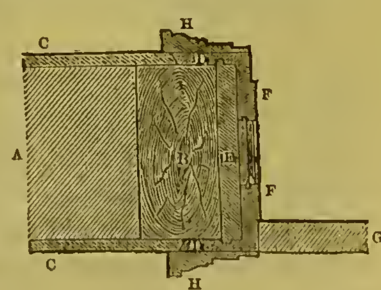


Fig. 55

out to the face of the plaster, and dispense with linings altogether. In walls of nine inches or more thickness, the jamb-linings are fixed to grounds or rough strips of wood, grooved in the same way as the linings in the preceding figure. In Fig. 55, A is the brick wall, B a wood brick built in the wall, and to which the woodwork is fixed, C C plaster, D D grounds, E backing, F F panelled jamb-lining, H H architrave moulding, G the doors. All this

Fig. 56.—Front Door of Terrace House.

appears to be somewhat complicated, but in reality it is as simple as is consistent with sound workmanship, and it is upon the proper and accurate attention to details of this kind that the efficient working of the various parts of the house depend.

A form of doorway frequently used in London houses, and introduced probably somewhere in the early part of the last century, is shown in Fig. 56. In houses where no side light can be obtained for the entrance hall, all the light possible must be obtained from the front, and in consequence of the confined width of the hall, there is no space for a window other than the narrow strips of lights on either

side of the door. The only way out of the difficulty is to form a window, or "fan-light," over the door. In probably ninety-nine cases out of every hundred where a fanlight exists over a door, it is made a fixture. As the fanlight is often the sole means whereby ventilation can be obtained, one would have thought that what is actually the exception would have been the rule, and that all fanlights would have been provided with proper means of opening and closing them. The apparatus for opening fanlights should be as simple as possible, and should be arranged in such a manner that if cords be used they are not liable to be cut in working over the pulleys. An apparatus, consisting of two curved metal arms, with a ratchet for keeping the light open at different inclinations, is made, and works well. There is also an apparatus made which consists wholly of metal, by which the fanlight is opened and closed by means of levers.

Windows.—In domestic buildings, windows formed of wood are ordinarily of two classes—double-hung, or sliding sashes, and casements. Of these two kinds of sash the preference for all ordinary purposes must unhesitatingly be given to double-hung sashes. This form of window, which was first introduced into England in the reign of William III., consists of two frames sliding vertically in parallel grooves. The upper sash is hung in the outer groove, to avoid making a lodgment for rain, which would be the case if the lower sash were outside. Each sash is hung by cords, which are taken over the wheels of pulleys, fixed as high up as the frame will allow, to which are attached iron or lead weights, which should be slightly lighter than the sashes. The lines and pulleys should be of as durable a nature as can be obtained. Some well-made form of metal rope is probably the best, and a pulley so constructed that friction is reduced to a minimum. Fig. 57 shows the construction of the frame, and the methods adopted for keeping the rain out. A is a section through the sash showing the arrangement of the sill, C is the oak sill, D the stone sub-sill. The bottom rail of the lower sash is bevelled to fit the upper surface of the sill, which is weathered to throw off the water. Immediately under the point where the outer edge of the lower sash touches it, the sill is stepped down about a quarter of an inch, and a groove cut in under the upper part; this is called throating, and is a further precaution against the ingress of rain. Grooves are also cut in the under side of the oak sill and the upper side of the stone sill, into which a thin bar or tongue of iron is inserted, and fixed with white lead.

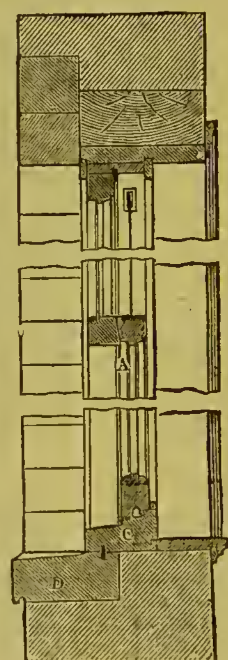


Fig. 57.

A Fig. 58. B

A plan has recently been introduced by which the sashes of an ordinary double-hung construction can also be opened on pivots if required. Without pronouncing an opinion on the merits of the particular invention referred to, the object sought to be obtained is a most desirable one, both for purposes of ventilation, and also for the ease with which windows fitted in this manner can be cleaned.

A simple mode, first devised by the late Dr. Parkes, for increasing the efficiency of double-hung sashes as means of ventilation, is as follows:—The lower sash being raised three or four inches (Fig. 58), a board of the depth required

is placed on the sill immediately under, and the sash shut down upon it (A). A current of air with an upward tendency is thus admitted between the meeting rails of the two sashes. This plan has been adopted in several hospitals with great success.

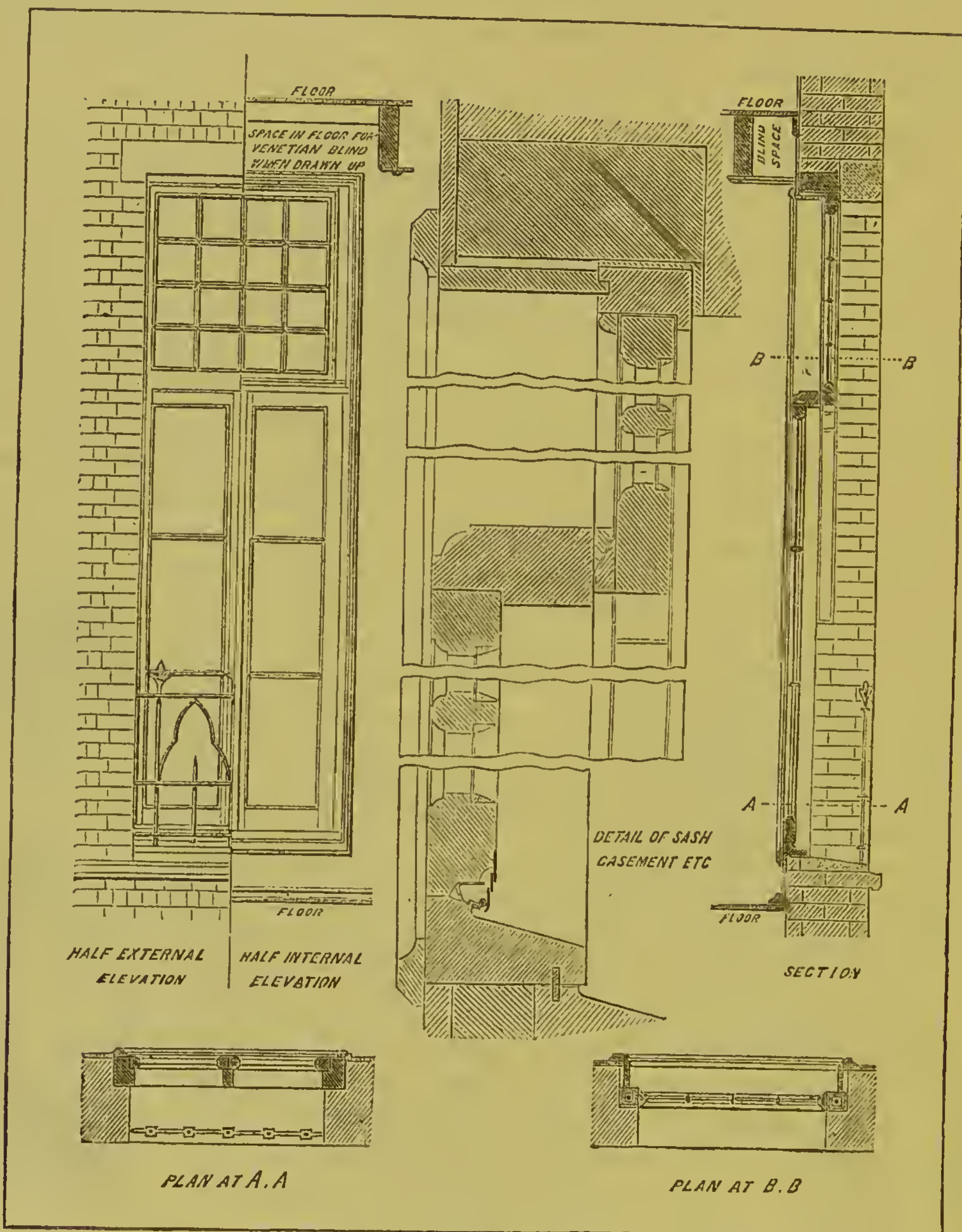


Fig. 59.—Casement and Sash.

A better way of accomplishing the same object is by making the bottom rail of the sash 5 or 6 inches deep, and fixing a board on the inner edge of the oak sill (B). It would be of great advantage if the lower sash of every window in a house were arranged according to the latter plan.

Casement windows are practically glazed doors, and may open either inwards or outwards. The weak point of this kind of window, and more particularly of those which open inwards, is the difficulty of keeping them weather-tight.

In exposed positions casements ought always to open outwards, so that

the effect of the wind pressing upon them forces them together when closed. Another objection to casements is the impossibility of nicely regulating the admission of air; for a casement cannot be opened at the top and not at the bottom. Lastly, when opening outwards, they are more difficult to clean.

Casement windows are, however, valuable from the large volume of air which can be admitted through them. For this reason they have recently been adopted, with the sanction of the Local Government Board, in the wards of some of the large Metropolitan Poor-law Sick Asylums. The accompanying illustration (Fig. 59) of a window, designed by Messrs. Saxon Snell and Son for this purpose, shows an ingenious combination of casement and sliding sash, which in practice is found to work admirably. All the joints are protected with india-rubber, and the precautions taken to prevent the ingress of rain have been found to be perfectly successful. The windows being directly opposite each other, by opening two pairs of casements a current of air the whole width of the window, and between seven and eight feet high, can be sent across the ward in a few minutes; while, when the windows are closed, patients can lie in bed within a few inches of them, and be absolutely free from draughts. Of course, such an arrangement as this is impossible except with the closest attention to details and the best possible workmanship; nor, on the other hand, would it be desirable to have windows absolutely impervious to draught without proper provision being made for a constant and sufficient supply of fresh air.

The first figure in the diagrams represents the external face of the window divided vertically down the centre, with the corresponding half seen from the inside. The upper portion, divided into small squares, is formed to draw down as a sliding sash. The larger scale details are sections through the various parts showing the precautions adopted for excluding rain and draught. An arrangement which might with convenience be more generally adopted is the provision of a space formed in the thickness of the floor above, into which the Venetian blind is drawn up out of sight.

When casements are required to open inwards, some such arrangement as that shown in Fig. 60 is necessary. There are several other contrivances for the same purpose, all more or less complicated, but it is not intended to describe here special appliances of this sort.

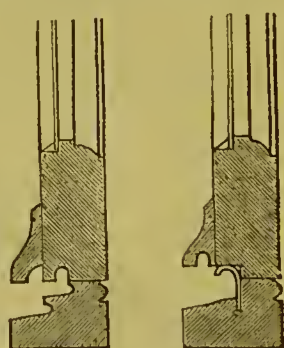


Fig. 60.

Fastenings.—Both kinds of windows require fastenings, to keep them from rattling when shut, and also for protection. Several kinds of sash fastener are available for sliding sashes, of which it will be sufficient for the present purpose to remark that the special qualities requisite are (1) to keep sashes well together, and (2) to render it absolutely impossible that the fastener should be opened from the outside, and this in as simple a manner as possible. This last condition is important, as if any mechanism of a complicated nature is employed, it is quite certain to be neglected. For large and heavy sashes, and where the ordinary fastening would have to be fixed out of reach, there are one or two contrivances made by which the sash is raised or lowered by means of cords, with drop handles fixed on each side of the sash. On letting go the cords, the sash is automatically fixed in any desired position. Casements require, besides a fastening to keep them closed, some kind of stay to keep them fixed open, otherwise the wind would blow them about and the glass would get broken.

Skylights and Lanterns.—In rooms where it is requisite to obtain the light from above—as, for instance, in kitchens, studios, and billiard-rooms—either skylights or lantern-lights must be constructed. The objection to skylights is their inveterate habit of leaking, though this may be, to a great extent, due to bad construction.

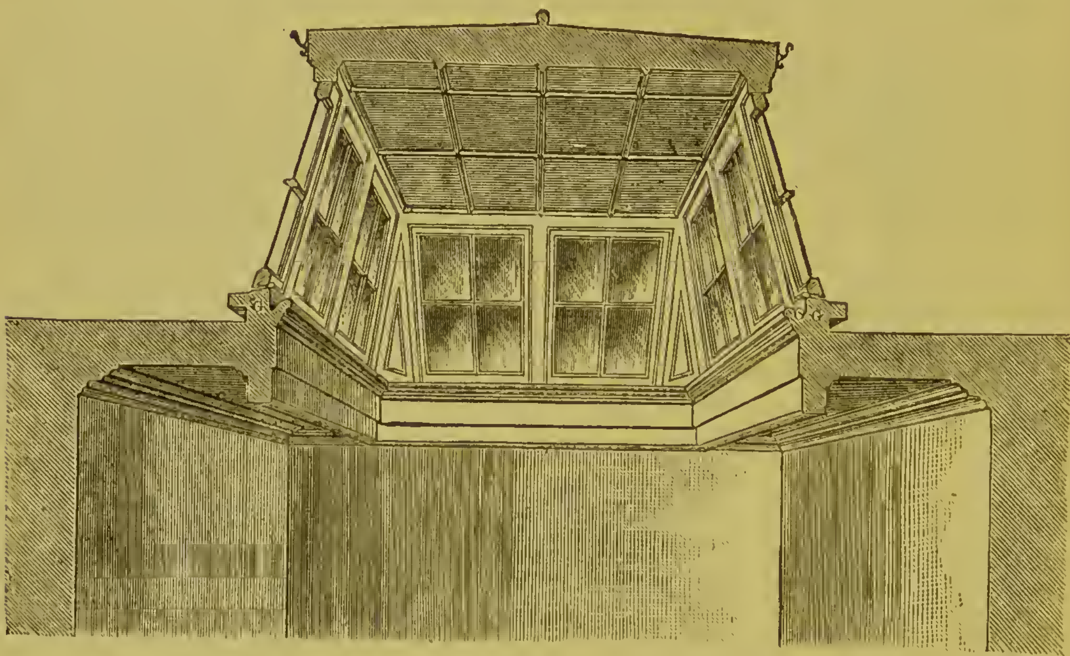


Fig. 61.

Where a direct light is not absolutely necessary, it is better to have such an arrangement as that shown in Fig. 61, called a lantern-light. The upright sides are simply rows of single sashes in solid frames, the frames forming the supports for the roof. The moisture condensed on the inner face of the sashes is received into a gutter at G, which is formed by carrying the lead under the sill, and dressing it into the hollowed-out surface of a wooden moulding; short lengths of lead-pipe convey the water through the sill on to the flat outside. Some additional advantage in the way of light is gained if the sides, instead of being vertical, are tilted in at the top. The most convenient inclination is three inches inwards to every foot in height. If the roof of a lantern is also a skylight, an additional condensation gutter must be provided at the higher level.

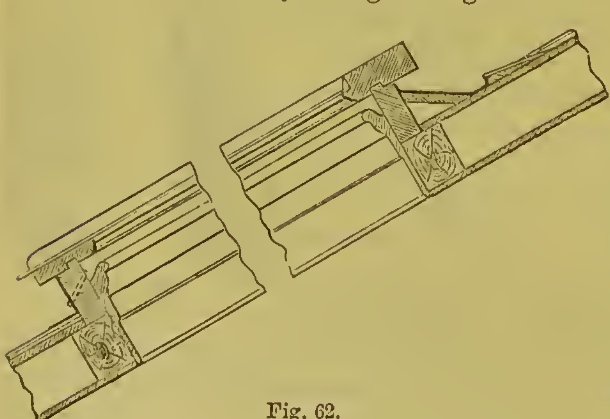


Fig. 62.

The following precautions must be observed in forming ordinary skylights (Fig. 62). The lead must be brought between the curb and the skylight, and turned round inside to form a channel both for condensation and for any rain that may chance to percolate; the under sides of the frame must be throated as shown in the section; and lastly, the glass, which should be carefully fitted to the woodwork, should be in one continuous pane, and should project about 1½ in. beyond

the bottom rail. If it is necessary to open a skylight, it should be hinged at the top. The upright lights in a lantern should be hung on pivots. The pivots ought to be fixed just above the centre, so that the sash will have a tendency to keep shut by its own weight. In studios it is often desirable to provide an arrangement of shutters to slide along the slope of the roof, and close wholly or in part the skylight.

Shutters.—Since the introduction of plate glass, shutters have in dwelling-houses, especially in London and the neighbourhood, fallen greatly into disuse. As, however, it is still desirable in some situations to provide some additional means of protection to the windows, it will be convenient here to describe the various ways of constructing shutters. They may be fixed either outside or inside. Inside shutters are of three kinds—sliding, folding, and coiling. Sliding shutters are formed on much the same principle as sliding sashes, and need no further description here. They are ordinarily used for the inferior rooms. Folding or boxing shutters are simply narrow folding doors, which, in the day-time, are stowed away in recesses or boxings on each side of the window to which they are attached. When they are thus folded away the outer leaf forms the jamb-lining to the window opening.

Coiling shutters, so largely used for shop-fronts, are formed of narrow curved slips of wood or metal, which are coiled away on a roller into a box above the window.

The only outside shutters calling for notice are those formed of open louvres in frames (Fig. 63). These are called jalousies, and are an importation from Italy. They are, in reality, blinds. They are extremely useful for windows with a sunny aspect, as they admit the air copiously whilst keeping off the direct rays of the sun. They are sometimes hung on hinges, like doors, and sometimes run on iron or wooden guides fixed against the walls.

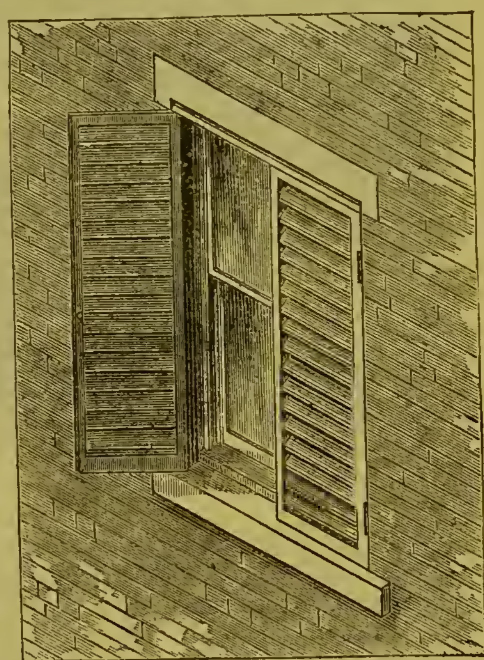


Fig. 63.

Stairs.—The position of the staircase governs and modifies the arrangement of the rest of the house, and no part of a house requires more careful study and contrivance. A staircase in which the relation of height of riser to width of tread is badly proportioned, or in which the flights are of inordinately long lengths, or which is screwed into some odd corner, and the deficiency of space eked out with winding steps as if the whole thing had been forgotten, and were stuck on at the last moment wherever it happened to come, cannot fail to be a lasting source of discomfort to the inmates of the house. Such an arrangement is however, unfortunately, by no means an uncommon one.

The relation of riser to tread should be based upon the following well-established scale of proportion :—

The width of the tread multiplied by the height of the riser should equal 66 inches. Thus if the tread be 9 inches wide, the riser should be $7\frac{1}{3}$ inches. If the riser be 6 inches, the tread should be 11 inches.

The rule adopted in France, where they have given great attention to the subject, is as follows:—"Inasmuch as, on the average, human beings move horizontally two feet in a stride, and as the labour of rising vertically is twice that of moving horizontally, the width of the tread added to twice the height of the rise should be equal to two feet."* It should be noted that the dimensions of stairs are always calculated as if the steps were square, the nosings being disregarded.

A wooden staircase of the simplest form is constructed in the following manner:—

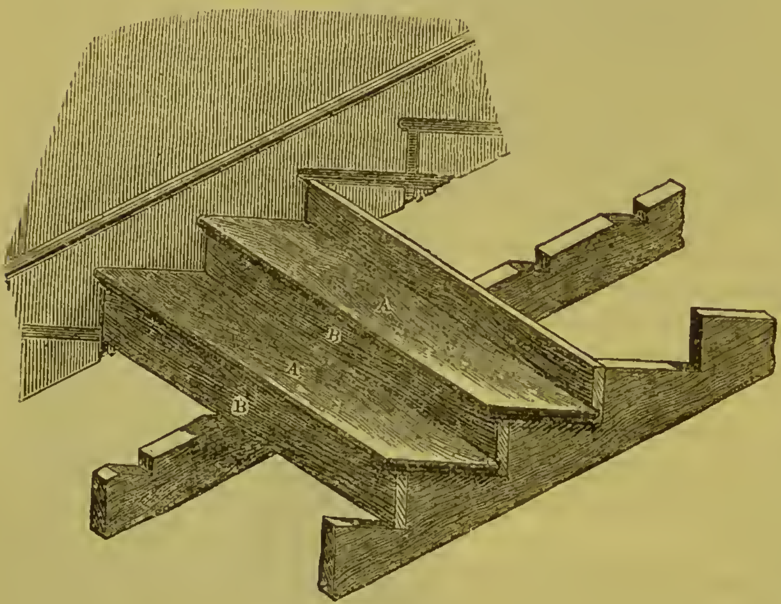


Fig. 64.

On the wall side, the treads, A A (Fig. 64), and risers, B B, are housed into a board about one and a half inches thick, called the wall-string, and which is grooved in the way shown in the sketch to receive the ends of the treads and risers. These grooves are shown to be considerably wider than the thickness of the steps, in order that wedges may be driven in after being well glued, and so make the work solid. On the other side, the string or board which supports the steps is what is called a cut string, being notched or cut out to receive the ends of tho treads, which are brought over with a return moulding. The risers are usually mitred to the outer string. Between the two strings are fixed, where the width of the staircase exceeds three or four feet, rough beams, usually called carriages, and to the side of these beams are nailed rough pieces of thinner boards, called brackets. Lastly, the under side of the steps are made still more solid by glueing blocks of wood in the inner angle (Fig. 65).

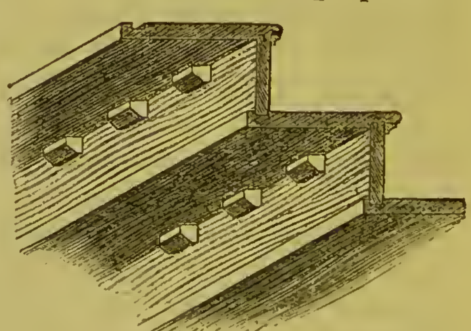


Fig. 65.

The usual thickness of treads for deal steps is one and a quarter inches, and for risers one inch. For longer bearings than four feet this thickness should be increased. The risers should be united to the treads by grooved and tongued joints, or by rebated joints.

The part of a staircase which is exposed to most wear is about three inches in depth, and about half to two-thirds of the width, at the outer edge, of the tread of each step. This can bo obviated in business houses, hotels, and other places where the traffic is considerable, by covering each

* "Notes on Building Construction," Part II., p. 323.

step with sheet lead turned round the nosing, and well nailed down with copper nails.

For staircases of a more expensive kind, oak and teak make excellent treads.

To support the handrail, it is necessary to have some kind of railing or balusters. The cheapest form of baluster is a square bar of wood, one inch thick. Balusters are also turned or carved with varying degrees of elaboration, according to the nature of the work and the expenditure contemplated. The distance between balusters should not exceed five inches. Cast and wrought iron balusters are also used. The height of the rail from the stairs should be from three feet on wide easy-going treads to two feet eight inches on steep stairs, the dimension being taken at the outer edge of the step. The handrail should be of such a section that will be easy and comfortable to hold, and should not be too wide. No doubt, a broad well-moulded rail is extremely effective in a large staircase, with every other surrounding to correspond; but in ordinary dwelling-houses the first requisite in a handrail is that it should be a ready and easy means of support to those requiring it. "If you want a large rail for appearance, it should be of this kind of section (Fig. 66), with a roll or cylinder at the top not more than two inches thick, and any ornamental shape you like below. The Gothic builders knew that, and made their handrails so; but the Renaissance people, who thought more of show than use, introduced those wide-topped monstrosities which seem made for boys to slide down rather than for anybody to handle."*

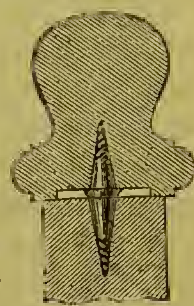


Fig. 66.

Another convenience that is often neglected in wide staircases is that there should be a second handrail fixed against the wall.

Two kinds of arrangements are available for staircases in ordinary houses. The one called a dog-leg staircase is where there is no space or well-hole between the outer strings; the other kind is called an open newel staircase, and includes all the varieties of staircases which have well-holes. Winding steps should be avoided, if possible; where it is absolutely necessary to use them, the width at a distance of eighteen inches from the handrail should be as nearly as possible the same width as the ordinary treads. By this arrangement the width of the winder-step where the traffic is greatest will be the same as that of the rest of the staircase.

* Sir Ed. Beckett: "Book on Building," p. 136.

CHAPTER XI.

DETAILS OF CONSTRUCTION.—PLASTERING, PAINTING, AND GLAZING.

Various Kinds of Plaster—Selenitic Cement—Painting—Substitutes for White Lead in Paint—Various Kinds of Paint—Luminous Paint—Varnishing—Glass and Glazing.

PLASTERING consists in applying to the surfaces of walls, for the sake of cleanliness, warmth, appearance, or imperviousness, various compositions in which lime or cement play a prominent part. That kind of plastered surface is the most healthy, as well as the most lasting, which possesses in the greatest degree the qualities of hardness and density, and capacity for taking polish. A wall faced with a porous plaster absorbs the moisture given off by respiration and evaporation, and with the moisture, organic and other impurities. Such a wall eventually becomes saturated with impurity, which can actually be scraped off and submitted to minute examination. It is therefore essential to adopt some means whereby a wall can be periodically cleansed from these impurities. For cottagers' and artisans' dwellings, where lime-white or distemper colour is all that is needed in the way of decoration, an ordinary well-plastered wall can practically be cleansed every time it is lime-whited or coloured; but for walls of a class superior to these, where custom demands a papered surface, the plaster should be of as unabsorbent a nature as possible, in order that the surface shall be entirely changed whenever the paper is renewed.

Although one of the objects of plastering the walls of a house or room is to make the wall more impervious, and preserve uniformity of temperature within the house, it must not be forgotten that many of the cheaper class of houses derive certain benefit from the perviousness of the walls. Professor Von Pettenkofer states :—"For a wall of dry brick we may calculate for each square metre (1·196 yard) of outside wall, and for each 1° C. of difference of temperature between the interior and exterior of the house, that from fifty-five to fifty-six gallons of air will pass through the walls of every house." * This may be a very valuable auxiliary to the ventilation of a house, and if the walls be coated with a dense plaster much of the benefit would be arrested. An interesting experiment, demonstrating the porosity of brick or mortar, is described in Dr. Hime's introduction to his translation of Von Pettenkofer's work. A cylinder of solid dry mortar, 5 inches long by 1⅔ inch diameter, is coated on the outside with wax, the ends being bare, and then at each end a funnel is fastened on by means of wax. By placing the tube of one of the funnels in the mouth, and blowing into it, a sufficiently strong current of air may be easily passed through the mortar to divert the flame of a candle held near the tube of the funnel at the other end. Of course, the more dense the plaster or cement with which a wall may be covered, the more perfectly is the interchange of air likely to be prevented, and the sanitary results will vary accordingly.

In India, Dr. Mouat, Inspector-General of Jails, recounts how the natives are in

* "Cholera : How to Prevent and Resist it." By Dr. Von Pettenkofer. Translated by T. W. Hime, B.A., M.B., 1875.

the habit of daily covering the floor and walls of their huts with a light coating of earth, containing a large amount of organic matter. By this means, he states, the animal exhalations are removed from the atmosphere, the air itself is purified, and an artificial renewal of oxygen is produced, which seems to be as efficacious as full and free ventilation.* This curious process, which is of great antiquity, is known in India as "leeping."

In the speculative building which goes on in the suburbs of most large towns the kind of plaster most commonly used consists to a great extent of a mixture of lime with sifted vegetable mould, and sometimes of materials even inferior to these. It is needless to point out that such a composition is of little use in any way. While undisturbed it adheres to the walls, and forms a smooth surface upon which to hang the wall-papering, and the paper is of considerable assistance in subsequently keeping the so-called plastering in its place; but wherever bedsteads or other pieces of furniture are frequently pushed against the wall, this plastering is rapidly damaged. It is a matter for regret that the power to require by bye-laws the plastering to be formed of good and proper materials is not authorised by the Public Health Act, in the same way as is permitted with regard to the materials used in the structure of the walls themselves of new buildings.

Ordinary plaster is composed usually of three coats or layers: the first, or "rough rendering coat" if on walls, "pricking-up" if on laths, is made with one or one and a half parts of sand to one part of lime mixed with long ox-hairs. The second, or floating, coat is made with fine stuff, which consists of lime slaked with a small quantity of water, and mixed to the consistency of cream. A little hair is added to this coat. This coat is named from the "floats" or "screeds" of plaster which are formed at the angles, and at intervals of from four to ten feet on the wall or ceiling. The surfaces of these are then brought into the required plane by passing long straight-edges over them. (See "Notes on Building Construction," p. 11.) The last, or setting, coat is a thin layer of "fine stuff," or it may be made with plasterer's putty, which consists of lime and water prepared in a somewhat different way from "fine stuff;" or lastly, it may consist of gauged stuff, a mixture of plasterer's putty and plaster of Paris. The object of using this last mixture is to insure rapidity in setting. It should be used only in small quantities. Trowelled stucco, a surface usually prepared for painting on, consists of two-thirds fine stuff, and one-third carefully-washed sand. Bastard stucco is made in the same manner, with the addition of a little hair. Keene's cement, Martin's cement, and Parian cement are all mixtures of calcined gypsum and other substances. Keene's cement is the hardest of the three, and is susceptible of a high polish. It is made in two qualities, the better of which is more purely white and takes polish better. Both kinds set hard.

Parian cement is also made in two qualities. It is generally thought to work freer than either Keene's or Martin's, but not to produce such sharp angles or mouldings.

Martin's cement is made in three qualities, the best or superfine being pure white, the other two more or less reddish.

It is well, when either of these cements is to be ultimately painted, to apply

* Report on the Statistics of the Prisons of the Lower Provinces of the Bengal Presidency, 1861—1865. By Dr. Mouat.

a coat of paint before it is dry. This greatly assists the application of the final painting when the surface is ready.

Selenitic cement, an invention of General Scott's, has several advantages over the ordinary processes which call for a description here. The following description is extracted mainly from the "Notes on Building Construction" before referred to:—

"This cement, like the other (Scott's cement), contains a small proportion of sulphate of lime, which is added in the form of plaster of Paris, mechanically mixed and ground with lime. Lime may, however, be selenitised by adding a small proportion of any sulphate, or by mixing it with sulphuric acid. The sulphate begins to take action directly the water is added. Its presence arrests the slaking action, causes the cement to set much more quickly, and enables it to be used with a much larger proportion of sand than ordinary lime without loss of strength.

"Selenitic clay is a preparation of clay and sulphate of lime, which, when added to a pure or nearly pure lime, confers upon it hydraulicity, and also the quick-setting properties of selenitic cement."

A surface fully equal to those of either Keene's or Parian cements can be obtained by the following mixture:—5 pails of water; 1 bushel of prepared selenitic lime; 3 bushels of prepared selenitic clay; 2 bushels of fine washed sand; 1 hod of chalk lime putty. A wall finished in this way can be brought to a high polish, and is readily washed.

Cornices and mouldings on ceilings are formed either with ordinary gauged stuff, or they may be cast in lengths in carton pierre or papier maché. Where great projection is required, wooden brackets are fixed to the ceiling-joists, the under surface of which are cut out roughly to the profile of the cornice.

Imitations of marble, known as "Scagliola" and "Marezzo Marble," are different preparations in which plaster of Paris plays an important part. As materials for internal decoration, and as surfaces of an absolutely impervious and washable nature, these inventions are not without their value, though Keene's cement answers all the purpose, without professing to be what it is not.

All salient angles of plastered walls should have angle staves of Keene's cement. Wood staves are sometimes used, but cement makes better work.

Whitewashing is a mixture of ordinary lime and water, and is used for common walls and ceilings.

Whitening is a mixture of whiting and size, and is applied to ordinary ceilings.

Clearcole is the coating of size which is applied to a ceiling to fill up the pores previous to whitening.

Colouring is merely the addition of some cheap colour with ordinary whitewash.

Distempering is done with whiting and size, with the addition of colour.

Painting.—The extensive use of a light-coloured soft wood, such as deal, for all kinds of joiners' work has doubtless been the cause of the application of paint to both interior and exterior woodwork. Paint forms at once a protection to the wood from atmospheric and other causes of decay, and a means of decorating the surface.

The surface to be painted, if of wood, must be first prepared in the following

manner:—The knots must be killed either by covering them with "knotting" or with hot lime. Patent knotting consists chiefly of shellac dissolved in naphtha. The object of these applications is to prevent the exudation of turpentine from the knots, and also to prevent the knots from absorbing the paint. In bad work the knots can often be plainly seen through four or five coats of paint.

The surface is then "primed" with a coat of red and white lead and linseed oil, in order to fill up the pores of the wood, and prevent the subsequent coats from being absorbed. The subsequent or colouring coats are then applied. These coats, with slight variations, are composed of a base, which is usually white lead, a vehicle, generally linseed oil, and a colouring pigment. Driers are often added to make the work dry quickly, and turpentine to make the paint work easily.

The base is the most important constituent of the mixture. It gives body and opacity to the work, and upon its quality depends the success of the finishing coats. The base most commonly used is white lead. This substance, which is a carbonate of lead, prepared by one or two processes, corrosion or precipitation, from the metal, has two serious drawbacks. The chief of these is its poisonous nature. The well-known painters' colic is produced by the use of white lead. A kind of paralysis also is caused by the absorption of white lead through the pores of the skin. The other disadvantage attending the use of white lead is that after exposure to the atmosphere it speedily loses its whiteness and brilliancy; in some conditions, as when exposed to the atmospheres of many manufacturing towns, or of some local impurities, it becomes positively black. In the case of iron a galvanic action is set up between the lead and the iron, which is injurious.

A substitute for white lead was devised by Mr. W. Noy Wilkins (a marine landscape painter), and adopted in 1878 by the Dean and Chapter of St. Paul's, under the advice of Mr. F. C. Penrose, M.A., their architect. The base used by Mr. Wilkins is kaolin (the china clay of Cornwall, a decomposed granite), mixed with a small proportion of zinc white. With this base Mr. Wilkins restricted himself to the use of mineral colours only.

Another substitute for white lead, which promises to be of considerable service to the builder, is the "Charlton White." This paint, which is the result of a series of experiments extending over several years, is an oxy-sulphide of zinc. It is prepared by precipitating sulphur with a solution of zinc chloride. It is perfectly free from all poisonous character, is not affected by sulphuretted hydrogen, and is quite neutral in contact with iron. The additional advantage is also claimed for this pigment that it has twenty-five per cent. more covering power than white lead, and that it will mix freely with paints which white lead destroys.

The best kind of oil for painters' work is linseed oil. "Raw linseed oil is obtained by allowing the oil, as first expressed from the seed, to settle until it can be drawn off clear."* Good linseed oil is pale, transparent, has a very slight smell, and is sweet to taste. It improves by keeping, and should never be used under a year old. Boiled oil is used when the work is wanted to dry quickly.

Driers are substances the use of which is to accelerate the solidification of the oil. They are made of various ingredients, such as litharge, acetate of lead, red lead, sulphate of zinc, verdigris, &c. The following precautions to be observed in the use of driers are given in the "Notes":—

* "Notes on Building Construction," Part III., p. 396.

1st. Not to use them unnecessarily with pigments which dry well in oil colour.
2nd. Not to employ them in excess, which would only retard the drying.
3rd. Not to add them to the colour until about to be used.
4th. Not to use more than one drier to the same colour.
5th. To avoid the use of patent driers unless known to be of good quality.
6th. To avoid the use of driers in the finishing coat of light colours, as they are liable to injure the colour.

Mr. Wilkins, whose application of kaolin and zinc white in the formation of a "base" has been mentioned above, found that by boiling a small quantity of Turkey umber in oil he obtained a vehicle which enabled him to dispense entirely with the use of driers.

Turpentine, or more properly oil of turpentine, is used as a solvent to make the paint flow more easily. It eventually disappears by evaporation.

Colouring pigments are made from natural earths, metals, vegetable substances, or artificial compounds of several ingredients. They are too numerous for description here; a few of the kinds to be avoided may, however, be noted.

Greens.—All green pigments are made either from copper or arsenic in some form or other. Those into whose composition arsenic enters should be avoided. The non-poisonous greens are Brunswick green, mineral green, and chrome green. Vienna green, Scheele's green, and emerald green are all highly-poisonous pigments.

Of blues, Indigo is not a durable colour, especially if mixed with white lead.

Amongst yellow paints the ochres are to be preferred to the chromes, the latter being apt to lose colour in bad air.

The most brilliant red next to carmine, which is too expensive for use in house painting, is vermilion. It is often adulterated with red lead, which much injures its colour and durability. The test of purity is heating the paint in a test-tube. If pure it will entirely volatilise.

The Silicate Paint Company manufacture a series of paints, into the composition of which it is stated that no injurious ingredients enter. Lead, arsenic, copper, and antimony salts are used in different ways to give brilliancy to many colours. To abolish these poisonous substances, and to substitute for them ingredients of perfectly neutral character, is without doubt a very valuable improvement on the score of health. These silicate paints are prepared from a pure silica obtained from the West of England. This is levigated, calcined, and mixed with resinous substances. Besides their non-poisonous qualities, these paints are said to stand 200° heat without blistering, to have no chemical action on metals, and to cover, weight for weight, double the surface of ordinary paint.

The same Company have patented a form of distemper which is called "Duresco." It is prepared from the "Charlton White" described above, and when applied to brick, stone, or plaster it hardens in such a manner as to indurate the surface. It is further claimed for this process that it is washable, that it is absolutely non-poisonous, and that it prevents the percolation of moisture. It also has the great advantage of being so easy of application that a labourer can apply it in a similar manner to whitewash.

The silicate enamel is a substitute for the expensive and delicate process of ordinary enamelling. It presents a hard polished surface, which is impervious and washable. It can also be used as a waterproofing composition for damp walls.

Another kind of paint, for which important properties as regards the preservation of iron are claimed, is the Torbay Oxide Paint. In the opinion of many eminent engineers iron ought to form the base of any protective covering for ironwork. It seems also necessary that, to attain the proper degrees of adhesiveness, elasticity, and covering power combined, the iron should not be in excess of the other ingredients. These qualities are, it is alleged, possessed by the paint now under consideration. The base of the Torbay paint is an oxide found at Brixham, in Devonshire. Into the process of manufacture it is not necessary to enter here. It will be sufficient to note the fact that the paint has now been in use for upwards of fourteen years, and that the experience of that period seems to have established the fact that it is not affected by extremes of heat or cold, or by the action of sea water; and that it has a remarkable affinity for and power of protection to iron.

Szerelmy's compositions are of three kinds. The first is for protecting the surface of stone from decay from atmospheric causes. It was used with some success in arresting for a time the progress of decay in the stone of the Houses of Parliament. It is also claimed for this composition that it is perfectly waterproof. The other two compositions are an iron paint and liquid enamel.

Besides the above there are several other paints, as the Granitic, Indestructible, Anti-corrosion, and others, for each of which some special advantage is claimed.

Luminous Paint.—An invention which stands quite by itself, and promises to be of wide importance for many purposes, is Balmaine's Luminous Paint. This remarkable paint was invented by the late Mr. W. H. Balmaine, a chemist of some eminence, who devoted much of his time to the special study of phosphorescent substances. The paint itself is a preparation of sulphur and lime, and has the remarkable property of emitting light for a considerable period after the luminous source is removed. For instance, it has been found that a lifebuoy thickly coated with the paint, when placed in the water, after being for several hours previously in darkness, emitted light so freely that it was plainly visible at a distance of a hundred yards. The value of such an invention, both for purposes of health and convenience, is obviously great. In bed-rooms, for instance, the dial of a clock, a bracket for matches, or a small contrivance for holding a watch, would obviate the necessity for burning gas all night. In hospitals, in the passages and water-closets, and possibly in the wards, at any rate those for convalescents, the free use of the paint might well supersede artificial light, and thus help to keep the air pure, as well as reduce the cost of lighting. Another most valuable purpose to which this invention might be applied is that of labels for bottles containing poison. The word "Poison" appearing as if written in letters of fire on the bottle would be a far better protection against the fatal mistakes which from time to time occur than any difference of colour or peculiarity in the form of the bottle.

Amongst other purposes to which this paint might be applied are the names and numbers on doors, especially in country parts where no gas exists—bell-pulls, letter-boxes, and, though not quite within the scope of the present subject, sign-posts and the names of streets.

Varnishes.—Varnish is a preparation of resin dissolved either in oil, turpentine, or alcohol. It is applied to painted surfaces, to paper-hangings, or to plain wood, either stained or not. It is chiefly useful as a means of obtaining a

hard, durable, and non-absorbent surface. When the surface to be varnished is porous, one or two coats of size should first be applied, otherwise the varnish will sink into the material and the effect be lost. The best varnish is that called copal. In applying it care should be taken that the surface to be varnished is perfectly free from dirt or foreign matters, and that the brushes used are perfectly clean and free from oil. It should be applied in thin coats, and the second and subsequent coats should not be applied until the preceding one is absolutely dry and hard.

Deal is frequently stained to give it the appearance of some darker sort of wood, and varnished with boiled linseed oil.

Glass.—The chief varieties of glass in use for building purposes are crown, sheet, and plate glass. Crown glass is blown in flat circular discs or tables, in the centre of which is the "bullion" or boss, so familiar in old greenhouses and outbuildings, where it was largely used, from the fact of its not being subject to the glass tax. Of late years these bullions have been much in request as ornamental features. Sheet glass is rapidly superseding crown glass, from the fact of its being procurable in much larger sheets. What is known as patent plate is sheet glass polished on both sides. It can be distinguished from real plate glass (called British plate) by the waviness of the surface and the form of the bubbles. In patent plate the bubbles are irregular in form, while in British plate they are always circular.

Plate glass is made by pouring glass at a white heat on to iron tables, and then rolling it out under heavy metal rollers. The advantages of plate glass are its strength, thickness, and translucency. The amount of light intercepted by plate glass and sheet glass respectively has been ascertained to be*—

Polished plate glass ¼-inch thick	13 per cent.
36 oz. sheet glass	22 per cent.

With thick glass the loss of heat by evaporation is much less than with thin glass.

Glass is usually fixed into woodwork by means of putty. The panes should be cut a shade smaller than the opening into which they are to be fixed, in order that the edges of the glass shall not come into actual contact with the woodwork. The putty intervening between glass and wood thus serves to deaden any jar received by the sash. The manner in which this object is attained is by what is called "back-puttying" (Fig. 67). A layer of putty, A, is first spread over the narrower face of the rebate B. Against this the glass C is pressed, and a portion of the putty is squeezed out and fills up the interstice D. Finally, the wedge-shaped front putty is applied. Large panes of plate glass are fixed in with wooden beads, and are frequently bedded in wash-leather or vulcanised india-rubber to deaden the effects of concussion.

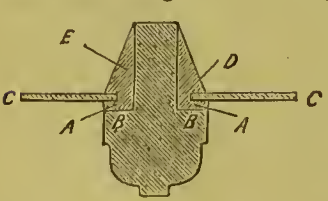


Fig. 67.

The method of glazing with small squares or diamonds of glass inserted in strips of lead, and known by the name of quarry or quarrel glazing, is performed thus:—A strip of lead is formed in section like the letter H. This is called

* Galton.

a "came." The desired pattern is then formed by soldering the cames together. To insert the glass, one side of the came is bent back, and turned down again when the glass is in its place. Windows glazed in this manner usually require saddle-bars of iron, to which the leadwork is fastened with copper wire. Large windows are often supported by upright stanchions fixed in the stonework, and to which the saddle-bars are affixed.

The practice of covering the walls of rooms with papers with patterns printed in colours is a comparatively modern one, and one that has been by no means an unmixed benefit to the health of society. The demand for a bright but cheap wall-covering has led to the production of wall-papers of gaudy hue, the very brightness of which is but too sure an index to the presence of poisonous colouring matter; but this point will be dealt with at length later on.

The custom, however, is a well-established one, and for decorative purposes a convenient one. The remedy must therefore be found, not in the abolition of wall-papers, but in an approved system of applying the colour, which shall fulfil the conditions required of brightness and cheapness.

Besides injurious consequences arising from the use of poisonous colours, the too frequent custom of hanging fresh papers on the walls of a room without removing the old papers, however many they may be, is one which cannot be too strongly condemned. When it is remembered not only that the paper itself is almost entirely composed of vegetable substances, but that the paste with which it is put on is vegetable also, and frequently not of the purest description, the readiness with which a mass of some half-dozen layers decays, and ultimately becomes putrid, is easily understood. To cite a well-known case in point. At the old Knightsbridge Barracks considerable annoyance, accompanied by some illness, was caused by a most intolerable stench. This was ultimately traced to the papered walls of the officers' quarters, which were found to be covered with numerous layers of papers one over the other, the innermost layers being in a state of putrid decomposition.

In re-papering old walls it is, then, of the first importance to clear away all vestiges of the old papers before proceeding to hang the new one. Of course in many instances this involves additional trouble in the shape of making good the surface of the plaster; the process of scraping off the old papers often resulting in small pieces of the plaster being detached. Additional trouble obviously means additional expense; hence the adoption of the custom at the expense of health. A good decorator will always clearcole his walls before papering. This is to be commended both on the score of cleanliness and also as affording a good surface for applying the paper.

Paste to be used for paper-hanging should be made of the best white wheat flour and clean water. Gum arabic, alum, and rosin are sometimes added for various purposes; but for all ordinary papers the pure flour paste is amply sufficient.

CHAPTER XII.

DETAILS OF CONSTRUCTION—METAL-WORK.

Hinges, Fastenings, Locks, and Handles—Smiths' and Ironwork—Rust—Plumbers' Work—Cisterns and Taps—Water-service Fittings.

Ironmongery.—The various appliances for opening and closing doors and windows, securing them from intrusion, and fastening them in their places, all have to be fixed by the carpenter, and are usually known as joiners' ironmongery.

It is not within the scope of the present work to recommend particular inventions, or, indeed, specialities of any sort. All that can be done here is to describe the apparatus best suited for the purpose, and to leave the reader to make choice out of the many excellent and ingenious things he will find ready to his hands.

Hinges are made of brass or of wrought and cast iron. The only object in using brass seems to be appearance; it is a bad material, both on account of its softness and its tendency to corrode. Probably the best kind of hinge is cast iron with steel pins. It is mistaken economy to use very narrow hinges. The leverage on the screws is materially reduced by using wide hinges, and the additional cost is not worth considering. Swing-doors are usually hung with a special contrivance at the bottom. The door fits into a metal shoe, which works on a pivot. This pivot is regulated by a spring, which is fixed under a brass plate flush with the floor. These are expensive things, but when well made and properly fixed they will last for years. About the best kind of hinge for a door that is intended to be self-closing is that known as a "rising butt." The part which is fixed to the door has a spiral action in an upward direction when opening, and thus the additional advantage is gained of a slight rise in the door, by which it is enabled to clear the carpet when opening and is closer to the floor when shut. Cross garnet hinges are used for the smaller kinds of outhouse doors, and strap hinges, with hook and ride action, for the larger doors and gates.

Many varieties of screws and nails are used in fixing joinery. It would be impossible here to enumerate them all, nor would it serve the present purpose to do so. In old joinery the work was put together with wooden pegs, usually of oak. In very first-class work this is done in the present day; indeed, in work not intended to be painted it is almost necessary to do so to avoid the unsightly appearance of nail and screw heads.

Locks for ordinary domestic work are of several kinds. Interior doors of a less thickness than two inches are usually fitted with a lock called a rim lock, the mechanism of which is enclosed in an iron box, which is screwed on to the face of the door. The box is usually made of cast iron, and japanned. Amongst recent improvements in the manufacture of rim locks may be mentioned the Anglo-American locks, which are of stronger make, better in design and finish, and better japanned than most English rim locks. The casting is clean and true, and the outer angles of the locks are rounded, and thus present none of those sharp edges which form such objectionable features in the ordinary lock. By a simple contrivance

inside the lock, the screws which fasten the plate on are not brought through to the surface. The mode of japanning by dipping the whole lock into the liquid japan, instead of painting it on with the brush, together with the much improved quality of the japan, greatly improves the appearance of the locks. The coarse and streaky appearance of many rim locks is due to the inferior quality of the japan, which, indeed, is frequently soft enough to come off with a slight rubbing. In America it is the custom to devote very much more care and expense to the ornamentation of rim locks than in this country, the outer plates being frequently elaborate and beautiful pieces of metal-work even in inexpensive locks.

When it is desirable to entirely conceal the lock, what is called a mortice lock is used. The object to be aimed at in a mortice lock is compactness, so that the style of the door shall not be unnecessarily cut into and weakened. This is successfully attained by a lock of American manufacture, in which the mechanism is arranged in so small a space that the mortice to receive it can easily be formed in the space between the tenons. The depth of these locks is only $1\frac{1}{4}$ inches, and the thickness $\frac{5}{8}$ inch. An additional advantage is the simplification of the labour of fixing. The top and bottom edges being rounded, the mortice can be made by simply boring two holes with a centre-bit, and cutting away the space between them, the labour involved in making the mortice rectangular being entirely dispensed with.

Another useful idea which is carried out by some lock-makers is to affix a number to each key and also to the plate of the lock. A register is kept of all locks and their destination, so that a lost key can be readily replaced or an additional key obtained merely by forwarding the number to the maker. It will be obvious also that such a system of numbering would obviate much inconvenience resulting from mixing up the keys of a large establishment.

Locks for front doors are nowadays commonly of small size, but are often of very excellent mechanism. One kind of lock for this purpose consists of a number of thin levers of brass or iron working side by side. Another kind is a solid bolt with a spring. Both kinds, when well made, are convenient and efficient. By an arrangement of small bolts acting on the levers, these locks can be counter-locked, so that the key cannot be worked; they can also be held open when it is so desired.

The usual method of fixing door-handles is a very poor contrivance. A screw, necessarily short, is inserted through the neck of the handle, to get what grip it may on the "spindle," or bar, which passes through the lock. The consequence of fixing handles in this way is that they are constantly coming off. A more secure way is that adopted by the American manufacturers before mentioned. The spindle is grooved, and the angles indented in a spiral direction. The inside of the handle is grooved in a screw form, and thus screws on to and retains a firm hold on the spindle; when it is in the required position, a screw is inserted in the neck of the handle, and screwed down into the deep groove on the spindle; this holds the handles firmly in their proper position.

Latches to street-doors ought always to have a plate or curtain over the key-hole to keep out the dirt.

The appliances for opening fanlights and casements and for fastening sashes

have already been mentioned. One additional apparatus ought, however, to be noticed here. It is what is known as an Espagnolette fastening, and is used for the double purpose of opening and closing a "French" casement and the water-bar arrangement at the sill simultaneously. It consists of a long rod which turns in, closing a quarter of a circle. At the bottom of this rod is a curved elbow, which, when the rod revolves in closing, pushes the water-bar into its place. When the use of such a fastening is imperative, care should be taken that the workmanship is the best obtainable; a badly-made contrivance is often worse than none at all.

Smiths' Work.—In building and fitting up a house, the aid of the smith and iron-founder must be called in to supply iron girders, stoves, cisterns, and any other constructive appliances or fittings which it is desirable to make of iron. Though iron girders of any great size are principally used for warehouse and factory building, it is sometimes necessary in large houses to employ a considerable amount of them. In town houses too, built in flats, it is necessary to make the floors fireproof, and for this purpose iron beams embedded in concrete are employed to carry the floors. It is impossible here to give an accurate description of the appearances of the different qualities of iron, or to enumerate the various tests by which the strength of a beam or girder can be ascertained; nor would it be of any real service to do so. The quality of iron ought to be examined by some competent person, and the strength tested by some such means as the very ingenious machinery invented by Mr. Kircaldy. These remarks apply, of course, to cases where a more or less extensive use of iron for constructive purposes is contemplated.

In arranging the sizes of iron cisterns, regard should be had to the position they are to occupy. They should not ordinarily be more than 3 feet 6 inches deep, and some provision should be made by which they can be cleaned out easily. A good plan is to make the bottom slope to the centre, with plug and hole to open when the cistern is empty. The size of a cistern should be calculated at 1 cubic foot for every 6½ gallons. A space of at least 3 inches in height should be left above the water-line. Iron cisterns should be galvanised—that is, covered with a thin coating of zinc, to preserve the iron from oxidation. This process answers perfectly so long as the coating is intact; when once the iron is exposed, either by the metal itself cracking or the coating of zinc being too thin or becoming damaged, the action of the atmosphere eventually destroys the iron.

Iron casements are mostly used when the framework or mullions of the windows are made of stone. They are usually made of wrought iron, and are furnished with very similar apparatus for opening and closing to wooden casements, but they are rarely weathertight.

Iron is also employed for columns, parts and sometimes the entire framework of roofs, eaves, gutters, pipes of all kinds, and for stoves and ranges. In America whole fronts of houses are constructed of cast iron framed and bolted together, and fashioned in such a way as to present the appearance of masonry. The result is not such as to encourage an imitation in this country. It may, however, be remarked that the use of iron for constructive purposes has scarcely had a fair trial in England. It yet remains to be seen how this valuable material can be honestly adapted to purposes of architecture beyond those to which it is at present applied.

One of the principal difficulties attending the use of iron in exposed positions is its tendency to oxidise, or rust. Rust is produced by the combination of the oxygen in the air and moisture with the iron, and, if not arrested or prevented, will gradually destroy the entire substance of the metal. Cast iron oxidises less rapidly than wrought iron.

In order to prevent oxidation, it is necessary to cover the surface of the metal in so complete a manner that no part shall be exposed to the action of the atmosphere; and in order to do this efficiently it must be done before the air has had a chance of commencing its deleterious action, and hence it is usual to give it a coat of paint or other covering substance before it leaves the foundry.

Galvanising has been mentioned above. The process consists of first cleaning the iron by steeping it for some hours in water containing sulphuric acid, then scouring with sand, washing, and placing it in clean water. The iron is then heated, immersed in chloride of zinc as a flux, and then plunged into molten zinc, the surface of which is protected by sal-ammoniac. As there is always the liability of the zinc coating becoming damaged or worn off, this process can hardly be regarded as entirely satisfactory.

Painting is, if properly applied, a tolerably efficient protection. Cast iron should be painted immediately it leaves the mould, before the air has time to act upon it. By this means the hard skin formed on the surface during the process of casting is preserved intact. Wrought iron, on the other hand, when it leaves the rollers, has a hard skin of oxide, which needs to be removed before the paint is applied. The most efficient process for effecting this is to dip the iron in dilute acid, by which means the scale is removed. This is, however, a costly process, and seldom employed in practice. The use of ordinary lead paints would seem to be objectionable, on account of the galvanic action said to be set up between the iron and lead. Mr. Matheson* recommends for ordinary ironwork oxide of iron paints, and for the inside of pipes bituminous paints.

A process invented by Mr. Barff seems likely to prove successful in preventing oxidation. The iron, after being carefully cleaned, is exposed in a chamber kept at a high temperature to the action of super-heated or "dry" steam. The steam being decomposed by the heat, its oxygen deposits on the surface of the iron a black or magnetic oxide, which is quite impervious to atmospheric action, and effectually protects the surface from oxidation. The power of resistance to injury which this oxide possesses depends upon the degree of heat at which the operation is performed and the length of time it occupies. Thus, if the operation be performed at a temperature of 500° Fahr., and for five hours, the coating will resist emery-paper for some considerable time. If the temperature be raised to 1,200° Fahr., and the operation be continued for seven hours, the oxidised surface will resist the action of a rasp, and, moreover, will not oxidise under any amount of exposure. An additional fact of value is that if, by any chance, a hole be left in the surface, the iron will rust in the ordinary manner, but the rust will not make its way under the surface of the magnetic oxide.

Dr. Angus Smith's process for the protection of iron pipes consists of immersing the iron, heated to 700° Fahr. in a mixture of coal-tar, pitch, and linseed oil, heated to 300° Fahr. The pipes are left in the mixture until they are reduced to the

* "Works in Iron."

temperature of 300° Fahr., when they are withdrawn, and put to cool in a vertical position.

Plumbing.—We now come to that branch of the building trade which causes more trouble and grief to the British householder than, probably, all the other trades put together. Every one knows—at least, every householder who lives in a house built by a speculating builder knows—the miseries attendant on a burst pipe or a ball-valve out of order. The plumber is sent for, and spends more or less of his valuable "time and materials"—generally more—at the householder's expense, and ostensibly for his benefit. The ultimate gainer is, however, not the householder, but the plumber, for the evil, whatever it be, invariably breaks out in a fresh place on the first opportunity. It certainly is not too much to say that ninety per cent. of the failures of the plumbing-work in ordinary houses of the villa and smaller classes result entirely from bad, ignorant, or dishonest workmanship. Thin pipes, bad joints, and improper materials are at the root of the evil.

The distribution of water about a house is a matter that ought to have more attention given to it than is usually the case. The arrangement of the various pipes from the point where they leave the main supply-pipe to the general-service cistern, and thence to the different parts of the house, is generally left to the intelligence of the journeyman plumber, who exercises his own ingenuity in fixing them, often in inaccessible places, and where they cannot fail to be affected by frost, to the serious inconvenience of the household. All pipes should be fixed in such positions that they are easily accessible without unnecessarily disturbing the walls and floors. It is important that the supply-pipe from the main in the street should be so placed as to be safe against the severest frost likely to occur. For this purpose it should ordinarily be buried not less in any part than from two to three feet beneath the surface of the ground, and in its course through the portion of the house to the cistern it should be carried along the walls: it should not be sunk in the walls or the plaster, as is frequently done with all pipes, to put them out of sight. The object of this is that the pipe may be more easily encased with felt or other non-conducting material, to protect it from frost.

The service-pipes from the cistern should be so arranged that by means of a stop-cock immediately under the cistern, or as near thereto as possible, the water may be shut off from the pipes, and they may be emptied whenever necessary, either for repairs or on the approach of frost. This is a most useful arrangement, and one that ought not in any case to be omitted. It is necessary to observe, moreover, that in fixing the pipes, every pipe should be so arranged as to allow it to empty itself completely when the supply has been shut off at the cistern by means of the stop-cock above referred to, and when the tap at the outlet has been opened. Water-pipes, as a rule, should not be fixed in positions where they are specially liable to draughts of cold air; hence they should not be placed immediately beneath a window, because in cold weather the current of cold air passing downwards from the window, even though the window be closed, is very liable under certain conditions to cause the water in the pipes to freeze.

Pipes for conveying water from the main supply-pipes in the roads are, in London, almost invariably of lead. The bye-laws of the metropolitan water companies compel the use of lead pipes when fixed under ground.

The following table, extracted from Mr. S. S. Hellyer's "The Plumber and

Sanitary Houses," gives the weights per yard of the kind of lead pipes which ought to be used for water-service in houses :—

Diameter.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.
	6 lbs.	9 lbs.	12 lbs.	16 lbs.	21 lbs.	28 lbs.

The size of the main service-pipe from the water company's main is usually fixed by the company. It must, however, vary with circumstances, such as distance, amount of storage, size of house, &c. Between the main and the first branch pipe a stop-cock should be fixed, so that in case of accident the water may be turned off entirely. Another stop-cock or valve is required by the London water companies to be fixed outside the house, for the use of their officers only. It is also advisable in cases where there are several cisterns, and more especially where there is a constant service, to have a stop-cock fixed in connection with each ball-valve, so that the water can be turned off from any one cistern without interfering with the others. In case of a cistern requiring to be cleansed, this arrangement will be found of service. Joints in lead water-pipes should always be of the form known as a wiped joint (Fig. 68). This joint is formed by inserting the end of one pipe, the edge of which has been previously rasped down, about ½ to ¾ of an inch into the other. The joint is then covered with molten solder until a sufficient thickness is obtained, when it is wiped round with a special kind of cloth. This kind of joint is the most durable for ordinary purposes of plumbing; for pipes for conveying water it is, indeed, the only one permissible under most water companies' regulations.

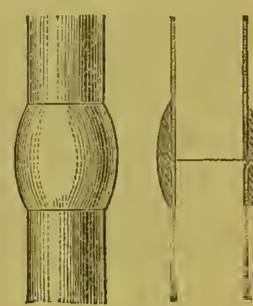


Fig. 68.

For the sake of warning the reader what to avoid, an illustration is here given of a blown joint (Fig. 69). This joint is made by blowing the flame from a bundle of lighted rushes on to the pipe to be jointed, and applying to the heated part the end of a stick of solder. It is not strong enough to stand any great pressure of water, and for this reason should not be permitted in domestic plumbing.

Fig. 69.

In all joints in soil, waste, or water pipes, care should be taken that the innermost pipe enters the outer pipe in the direction of the current, otherwise the ledge which must necessarily be formed will become a harbour for any dirt or foreign matter that may chance to be in the water.

In cottages, artisans' dwellings, and in any situations where lead pipes would be liable to be injured, or stolen for the sake of the metal, galvanised iron pipes should be used.

The flow of water into a cistern is regulated by an apparatus called a ball-valve. The principle of the ball-valve is this :—A hollow ball, which ought to be, and usually is, made of copper, works on the end of a lever. This lever is attached to a valve fixed on to the open end of the supply-pipe in such a manner that when

the water reaches a certain level in the cistern, the ball, floating on the surface of the water, closes the valve by means of the lever arm. As the surface of the water descends by the water being drawn off, the ball descends with it, and gradually re-opens the valve. It is a point of the greatest importance, both for the water companies and the consumer, to insist upon the ball-valves being of the best and strongest description. It was calculated lately, and probably on good foundation, that in one street alone in a provincial town, which provides its own water-supply, over 2,000 gallons of water a day are wasted, solely by the inefficient ball-valves and other fittings. In order to see that the ball-valves are acting properly, it is well to have a contrivance of some such kind as this (Fig. 70) :—A is the ball, B the water, C a hollow float of zinc attached to a chain or cord and balance-weight. The cord, running over pulleys, raises or lowers the balance-weight with the rise and fall of water in the cistern. It is also useful as an index to show the amount of water in the cistern.

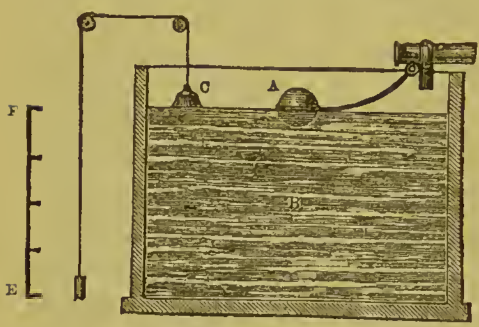


Fig. 70.

Taps for drawing water for use are made either in brass or gun-metal. They are of three kinds, known respectively as "plug," "spring," and "screw-down." The plug tap is the ordinary old-fashioned tap, in which the water is turned off or on by means of a plug with a handle. It is objectionable for two reasons: first, because the act of closing the tap forces back the column of water with so sudden a concussion that the pipe is weakened, and eventually not unfrequently bursts; secondly, the construction of the tap is such that repairs are costly, and must be executed by skilled workmen. These taps are prohibited by the Regulations made under the "Metropolis Water Act, 1871," by the Board of Trade.

Spring taps have one advantage only over plug taps—that of preventing the possibility of waste by leaving the tap open. They are, however, equally objectionable, as causing a sudden concussion in the pipe. This kind of tap is also prohibited by the regulations before mentioned.

Screw-down taps have the advantage of stopping the water gradually without any concussion. It would appear also that, notwithstanding the tendency not to shut these taps off completely, there is actually less waste involved in their use than with either of the other kinds. Hence this description of tap is the one specified as permissible in the "Regulations." Another advantage possessed by this tap is that it is easily repaired, and that frequently without the necessity for employing skilled labour.

Taps for supplying hot and cold water to baths should always discharge over the highest level of the water in the bath; the old-fashioned three-way cocks, by which the same orifice in the bottom of the bath did duty for both supplies and waste, being most objectionable.

The London water companies usually require that all taps shall be of the "screw-down" kind. These taps have the advantage of not shutting off the water with a sudden jar, as is done by the ordinary bib-cock.

Bath taps can be made in the same way, and are greatly to be preferred to

the old and expensive taps which work with a long rod from the upper edge of the bath to the pipe beneath. Bath taps may with advantage, in houses where a housemaid's closet of sufficient size cannot be arranged, be made to discharge far enough over the edge of the bath to allow cans and jugs to be filled from them. A kind of tap is also made which requires to be held open, or it shuts itself with a weight. For flushing out slop-sinks a screw-down valve should be used, and arranged in such a manner that the water takes a spiral direction in the basin. For lavatory basins there are nothing better than the valves with pull-up action. They are self-closing, and can be fitted up with any degree of taste and ornament. Ivory, ebony, and plated mountings are all appropriate.

As a rule, as already stated, all water-closets and baths require lead trays to be formed underneath, to intercept and carry off the drippings and overflowings certain to occur sometimes. This tray, or "safe," as it is called, should be cut out of one piece of lead, weighing five or six pounds to the superficial foot, turned up four inches all round, and soldered at each angle. A short piece of waste-pipe discharging in the open air is fixed at one end of the safe, which must have a slight fall to the pipe. Mr. Hellyer recommends that all slate and iron cisterns should have safes also. In practice this is very seldom done, but it is a precaution which ought always to be taken, as the condensation on the under surface, especially of iron cisterns, is often very considerable—quite enough, indeed, at times to spoil a ceiling, if there happen to be one underneath.

CHAPTER XIII.

FITTINGS.—BATHS, SINKS, AND WATER-CLOSETS.

Baths—Lavatories—Water-closets—Evils of the Common Pan-closet—Various improved Systems—Precautions in Use and Care of Closets—Flushing Arrangements—Sinks.

UPON the quality and arrangement of these fittings will depend so much of its convenience to the occupier that attention to them is indispensable in every house.

A house that contains some special contrivance by which even a small amount of labour may be saved, or which may afford some special satisfaction to the intending occupier, will invariably be selected sooner than a similar house without such contrivance. This may mean avoiding the loss of a quarter's rent, or the retention of a tenant for an indefinite time who would otherwise leave the house on the landlord's hands; and in this, if in no other way, the careful arrangement of the internal fittings of every house must be regarded as likely to fully justify any extra outlay they may involve. Hence it is necessary to consider the fittings and fixtures of a house, to their smallest detail, with the utmost attention.

The object of most fittings and fixtures is to increase convenience and comfort, to diminish labour, and to promote cleanliness and tidiness. Thus we have baths, lavatories, indoor water-closets, sinks of various descriptions, and hot and cold water supply on upper floors, cupboards and closets for clothing, linen, and general stores, various arrangements for preparing food and keeping and cleansing the appliances used at meals. Then there are the bells, speaking-tubes, and telephones, or other means of communication with the inner and outer world, serving-hatches, lifts, coal-stores upstairs, soiled linen places, &c.

The habit of bathing is of very ancient date. In the East, bathing and ablution have formed part of the religion for many centuries. In ancient Rome, where, unlike modern London, water of excellent quality was available for everybody in unlimited quantities, the use of the bath was very general. Both private and public baths were numerous, and the latter, as can be seen from their ruins, were of great extent and magnificence, comprising buildings of the grandest proportions, containing colonnades, and halls of various sizes, adorned with the finest paintings and sculptures. The habit of bathing, common among the Romans, was imported by them into this country; for numerous remains of Roman baths have been discovered in various parts of England. The grandeur and extent of the baths of Rome was undoubtedly due to the extraordinary quantity of water with which the city was supplied by means of aqueducts; and when our own metropolis and large provincial towns receive the bountiful supplies of water which some of them have been contemplating, it is to be hoped the use of the bath, which has already greatly increased during the last thirty or forty years, will become still more general throughout the country.

Baths such as are ordinarily fixed in private houses are made of copper, cast-iron, tinned iron, zinc, slate, glazed fire-clay, or porcelain, and, within a recent

period, concrete. Baths are also sometimes formed of brickwork, and lined with tiles or glazed bricks, but, owing to the number of joints, these are not very satisfactory. The metal baths are usually, though not invariably, painted or enamelled in imitation of marble, but this covering material is very liable to damage and come off. With cast-iron this is specially likely, partly owing to the metal being less elastic than copper and zinc, and partly owing to the fact that iron is so readily oxidised when in contact with moisture. Iron baths are comparatively inexpensive, but they change colour after a time, and do not look as clean and nice as is usually desired. Zinc baths are also inexpensive, but they are not so durable as copper baths, and unless they are specially supported underneath with proper wooden framework, they are apt to get out of shape with constant use, and they then fail to let all the water run out. Copper baths are the most costly and durable of metal baths, and, on the whole, are perhaps the best for ordinary private use.

Slate baths are generally enamelled in imitation of marble, but the enamel is liable to damage, and when chipped off gives an untidy appearance to the bath. Slate baths, when not enamelled, have the disadvantage, owing to their dark colour, that it is difficult to see when they are thoroughly clean. Slate baths, moreover, have to be put together in slabs, and unless the work is exceptionally well done, they are liable to leak at the joints. From the same cause, moreover, they have square angles and corners, which it is difficult to keep permanently clean.

Glazed fire-clay baths, on the other hand, being formed all in one piece, have carefully rounded angles and corners, in which dirt cannot well accumulate. The substance of fire-clay baths is very durable, and the glaze is not easily damaged; while the colour—a white or pale cream—allows any dirt to be at once detected. These are all considerable advantages, and entitle this kind of bath, which is said to have originated at the suggestion of the late Prince Consort, to the large share of praise usually accorded to it. Its disadvantages are its weight and cumbersomeness, and its power of absorbing heat from the hot water put into it. These baths are also rather costly, owing partly to the length of time and great heat necessary in baking them, and partly to the large proportion that are damaged in the process of baking. If, however, one is selected with a slight blemish in the upper part, where it would not in the least be prejudicial to the use of the bath, a considerable reduction in the price is usually made.

Concrete baths are of quite recent origin. They are cast all in one piece, and possess some of the advantages of fire-clay baths, and are cheaper. They are, however, heavy and cumbersome. An advantage possessed by concrete as a material for baths is that it is not affected by the use of sulphur and other chemical preparations used in medicinal bathing. This fact is not without importance, though it is one that does not apply to the majority of baths.

In these days, when baths are held in such estimation as necessary for health and vigour, when bath-rooms are attached to every suite of rooms in the better houses and hotels, and when every new house of forty-five or fifty pounds' rental value is considered incomplete without its bath-room, it is of advantage if the ordinary bath can be supplemented by a shower-bath. This may be effected with very little difficulty, and affords a most invigorating adjunct; in fact, no bath-room

should be considered complete without a shower-bath, for, although the latter may be but little used in winter, it produces a most refreshing sensation when used in summer.

It may be expected that before many years have elapsed it will be deemed an essential in every bath-room in the houses of our principal inland towns, no less than in those near the coast, that, besides hot and cold water, a third tap should be furnished for the supply of sea-water; for already sea-water is daily brought to London by railway from the east coast, and projects are on foot for a systematic supply to the metropolis by pipes from the south coast. In some sea-side towns arrangements already exist by which sea-water is carried in mains to various parts of the town, for use in watering the roads, and it would not be difficult to lay on this water to the houses in the neighbourhood.

Wherever a bath is fixed, it is usual to cover the floor beneath it with sheet lead, turned up an inch or two all round, so as to form what is called a *safe*, in order to prevent damage to the ceilings immediately below in the event of the bath overflowing from any cause. The safe is, of course, provided with a suitable waste-pipe.

Where portable baths of various sorts are in use, such as sponge-baths, hip-baths, &c., it is convenient to provide a safe about eighteen or twenty inches deep, when it forms an excellent place in which to use a shower or sponge-bath; or, indeed, where water is plentiful, to use this deep safe itself as a sort of miniature swimming-bath for children.

Whatever kind of bath is adopted for a house, it is important to have means of rapidly emptying and charging it. This is a point often neglected by builders, the result being that where, as is more often the case, there is but one bath in a house, the delay of preparing it for use immediately after a person has bathed in it frequently leads to its use by a second or a third person being dispensed with. The waste-pipes should be not less than two inches diameter, and the supply and overflow pipes proportionately large. The holes in the grating at the outlet of the bath, as well as the water-way through the waste-valve, should of course be arranged so as, in the aggregate, to allow a free passage equal to the sectional area of the waste-pipe.

For the supply of water to a bath it is not uncommon to find an arrangement under which, by a system of valves, both the hot and the cold water enters the bath at the same orifice as the discharge or waste pipe. This is a plan which can scarcely be too strongly condemned. The outlet from a bath will always have a certain amount of soapy and other matters clinging to its sides after the bath has been used; and when the bath is refilled through the same channel, this will be carried back into the bath, thereby contaminating the water. The clean water should always be admitted to a bath at a point above the ordinary level of the water in the bath. For baths used by young children and in schools it is advisable that the hot-water tap should have a movable handle or "spanner," to be kept, when not in use, out of reach of the children, in order to avoid the possibility of the children improperly turning on the hot water and scalding themselves.

It is usual to case in the bath with framed and panelled woodwork; but this would be better omitted, in order that the space under and around the bath may be visible and easily kept clean. Baths are now very commonly made with

ornamental feet, and the sides enamelled in imitation of marble, in order to obviate the necessity of casing.

Lavatories in the ordinary sense are fixed wash-hand basins, with water laid on to them and waste-pipes from them. They are less indispensable than baths, because an ordinary wash-hand stand with basin and ewer will answer the purpose. Fixed lavatories, however, especially when supplied with hot water as well as cold, are more or less of a luxury. They are rarely fixed in positions where an ordinary wash-hand stand may be used, such as in bed-rooms and dressing-rooms, doubtless mainly because of the objection to having anything in the form of a waste-pipe actually in the sleeping-room. There is no reason, however, why, if the mode of getting rid of the waste water is satisfactorily and properly arranged, fixed lavatories should not be more largely adopted for ordinary use than is commonly the case. Indeed, in some houses and hotels very great advantage results from the arrangement, inasmuch as there is a considerable saving of domestic labour in supplying clean and removing dirty water, and wherever this can be done, even in a small degree, it is obviously of much advantage. Where there may be objection to fixed lavatories in the habitable rooms of a house, it is nevertheless useful to provide them in some position common to all in the house, so that by their use at odd times during the day, the bed-rooms may be kept tidy, and thus save some labour upstairs. This is one reason why in most hotels ample lavatory accommodation is provided on the ground floor, thus avoiding the necessity for visitors resorting to their bed-rooms as often as they would otherwise have to do.

Lavatory basins, like baths, are made of various materials—iron, tin, earthenware, &c.—but the best are of stoneware. They are sometimes made in one piece, combining the basin, the lavatory top with its soap and brush trays, &c., or they are fixed in a slab of marble or slate with ordinary supply taps and waste-pipes. Many improved lavatory basins and fittings have in recent years been introduced, among others the "tip-up" basin, in which the basin is hung on pivots at the sides over a funnel-shaped receptacle which receives the waste water when the basin is emptied by tipping it up, and carries it away to the proper outlet. The way in which the details of this apparatus are contrived is most ingenious, but the apparatus has the disadvantage of presenting a large surface beneath the basin which is apt to become foul and offensive if not frequently cleansed.

Various contrivances have been devised in order to obviate the objection that arises from the deposit of soap and dirt on the sides of a wash-hand basin when the water is being discharged from it after use. One method that is attended with a certain amount of success is to introduce the clean water at holes all round the top, but perhaps the most important point in this respect is to secure rapidity of emptying the basin by making the outlet of ample size. Any plan by which the basin is charged and emptied through the same orifice is more or less unsatisfactory. A plan is adopted in some schools by which each child washes at a small jet of running water which issues from a nozzle in a continuous pipe, and falls into a trough or channel on the floor, in order to preclude the possibility of any child using water that may be at all contaminated, either by previous use or by contact with an imperfectly-rinsed basin, thereby affording the means of communicating certain diseases. In this way the head and the upper

part of the body of every child is effectually washed. The system has been in use for many years at the Royal Military Asylum at Chelsea, and likewise at many of the Poor Law Schools.

The question of the kind of water-closet apparatus that should be adopted is one that exercises the mind of most persons concerned in the fitting up of a house. Indeed, it is a question that calls for most careful consideration by every householder and person intending to take a house; for even if the drains are perfect, the soil-pipe effectually ventilated, and the closet itself well arranged,

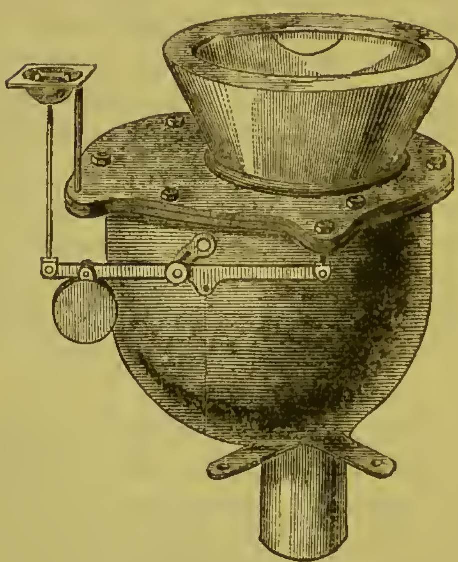


Fig. 71.—Pan Closet.

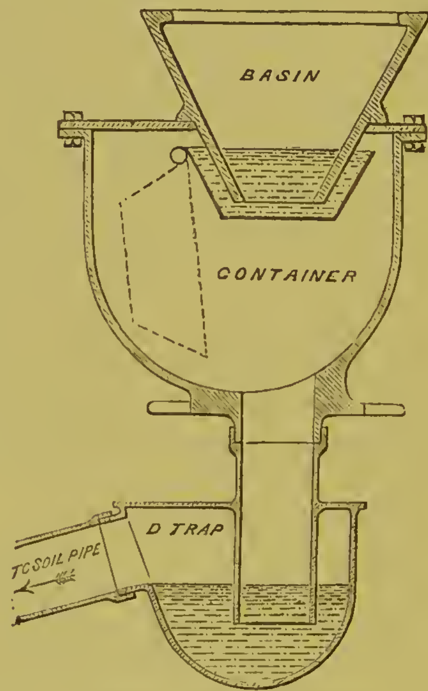


Fig. 72.—Section of Pan Closet.

it is possible to have a water-closet apparatus that will itself comprise all that is necessary to produce the most offensive smells and the most unwholesome air.

The kind of closet for indoor use that is most open to objection is one that is at present more commonly met with than any other. But it is to be hoped that before long the public will learn to insist upon some other and better kind of apparatus being substituted for it. The apparatus referred to may be seen illustrated in the advertisements of many newspapers connected with building; it is frequently exhibited in the shop window of the ordinary "plumber, painter, and glazier;" and it is introduced by the ordinary builder in the water-closet of almost every new house. This apparatus, which is indicated in the annexed diagram (Fig. 71), comprises in its complete form three important parts—namely, the earthenware basin, the iron "container," and the lead D trap (Fig. 72). The "container" is the iron box in the top of which the basin itself is fixed, and holds the metal pan which forms the trap immediately at the bottom of the basin. This closet derives its name of "pan closet" from this metal pan, which receives the discharge from the basin, and passes it on to what is known as the D trap. This trap, as its name implies, is somewhat in the form of the letter D. It is placed

with the straight side uppermost, and receives a pipe therein from the container, which pipe descends to near the bottom of the trap, so as to discharge below the level of the water in the trap. The outlet from the D trap is by a pipe passing out near the top, and is connected directly with the soil-pipe.

This kind of apparatus possesses the cardinal objection that it comprises two consecutive traps, ordinarily without any intermediate ventilator, and thus the lower one, or D trap, acts upon the upper one (the pan) each time the closet is used, and this accounts for the regurgitating noise so often heard immediately after the basin in the closet is emptied. It is, however, the container and D trap themselves which make this particular apparatus chiefly objectionable. The interior of these appliances becomes coated with a most filthy slime—the natural deposit of the matters that are passed through them and that are often retained for hours in them—and it is this deposit which emits the offensive and unwholesome smell so frequently met with when the handle is pulled up for the basin to be emptied after use. The annexed illustration (Fig. 73) will afford some idea of the condition of the interior of an ordinary D trap after it has been in use some months. This arises from the amount of surface upon which deposits can take place, and which, not being exposed to the full force of the flush, rapidly accumulate and putrefy. Such deposits, moreover, are encouraged by the use of iron, of which the container is almost invariably made.

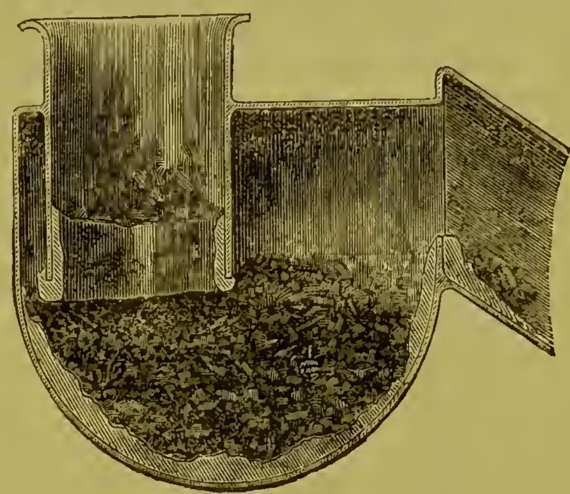


Fig. 73.—Section of an old D trap.

In the selection of a water-closet apparatus, the chief points to be looked for are—

(1) A basin of suitable shape to hold a sufficient quantity of water, and of a size which shall ensure the perfect and constant cleanliness of the basin's sides.

(2) The basin should be of glazed stoneware, and it may be observed that a plain white basin is infinitely better than one with a quantity of printed ornament or advertisements upon it, which prevent any dirt on its inner surface from being readily detected. Such a basin, too, will also readily permit the contents to be seen after use—a matter of no little importance where the state of the health is carefully observed.

(3) The trap beneath the basin should be of the simplest form, without angles of any kind, and so arranged as to preserve continuity of circular section. This is best supplied in the ordinary so-called "syphon" trap, or S trap, formed of glazed stoneware, and which, in the best closets, is in one and the same piece as the basin itself.

(4) There should be as much absence of metal-work about the apparatus as possible. All metal-work involves joints, and joints are liable to leak. Metal-work, moreover, easily corrodes, and encourages the deposit of offensive matter.

The careful observance of these principles will result in the rejection of any

closet apparatus which comprises a "container" and D trap; also any apparatus or basin of a "hopper" or funnel shape, in which the foul matter does not fall directly into the water, but is liable to slide down and foul the sides of the basin.

In schools and many institutions the water-closets or latrines are arranged so as to have a cast-iron trough under a range of seats. This is open to the objection above pointed out with respect to all metal-work in water-closets. A far better arrangement is to have the trough made of plain white glazed fire-clay, which does not so easily get foul, but permits any dirt on the inner surface to be readily detected and removed. These trough closets, however, are not adapted for use within inhabited buildings, inasmuch as, owing to the fact of their being intended to be emptied only at regular intervals, they involve the retention therein of the offensive matter for a certain, or rather an uncertain, length of time,

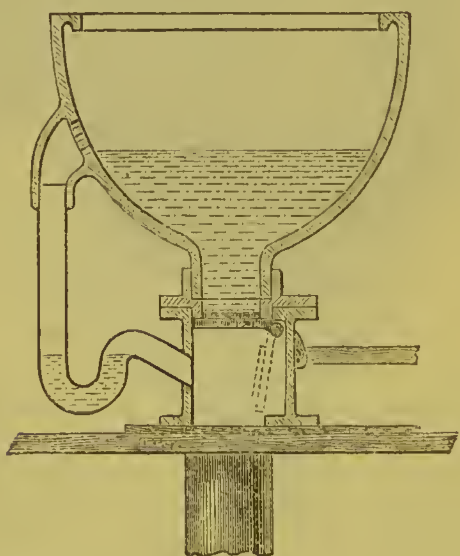


Fig. 74.—Valve Apparatus.

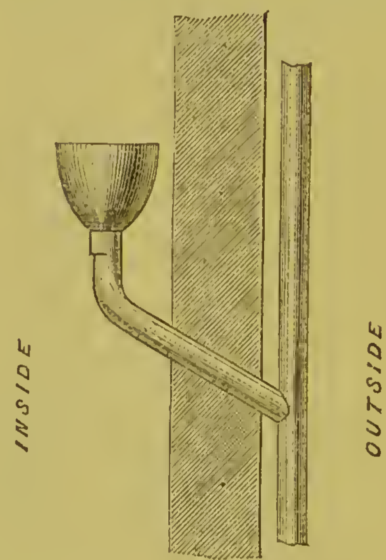


Fig. 75.—Direct Connection.

and this is clearly open to much objection if the trough is situated indoors; and, moreover, unless it has systematic attention, it is liable to get very offensive.

The trap beneath the basin of an ordinary water-closet apparatus, besides preventing a back flow of air, is necessary for maintaining permanently a certain quantity of water for the reception of solid matter. If the soil-pipe and the house drains are properly arranged and always in the condition in which they ought to be, the trap would not really be an essential were an ordinary valve, closing the outlet at the bottom of the basin, as in Fig. 74, provided, so as to keep the requisite quantity of water therein, and prevent the back flow of air. When the valve is opened the contents of the basin pass at once into the soil-pipe. In some respects a valve apparatus is preferable to many others, because it is less complicated. A trap, even in the simplest form, cannot fail to be an impediment to the flushing power and free flow of the contents of the basin when discharged. Hence there is advantage if it can be dispensed with, and where the drains and soil-pipe efficiently answer their purpose an apparatus with merely a valve or other method of retaining the quantity of water in the basin, without any trap beneath as part of the structure of the apparatus, would be quite permissible

(Fig. 75). This system is now occasionally adopted where intelligence and good workmanship are bestowed on the building; but if the drains are no better than such as are usually formed by the ordinary builder, it would clearly be an unsafe arrangement to adopt.

A valve closet, however, is not always free from objection, inasmuch as the valve itself, being chiefly of metal and difficult of access, cannot well be kept clean and free from offensive matter. An effort has been made to remedy this defect by substituting a plug for the metal valve in certain so-called trapless closets, the water being kept in the basin by a plug edged with india-rubber, and the quantity of water regulated by means of an ordinary ball-cock. Plug closets, however, with

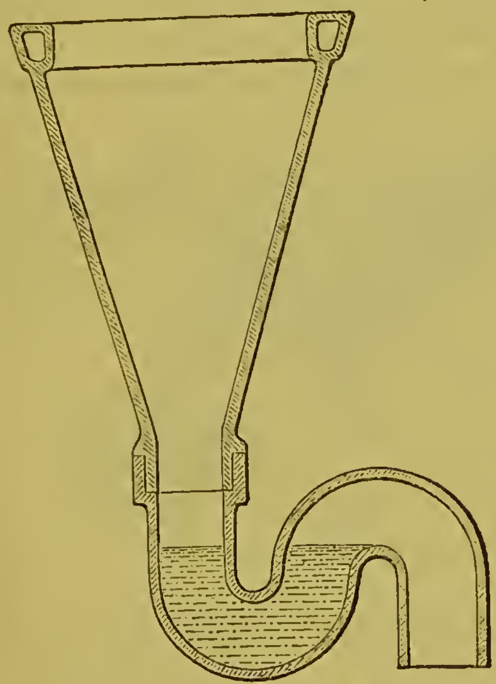


Fig. 76.—Trapped Basin.

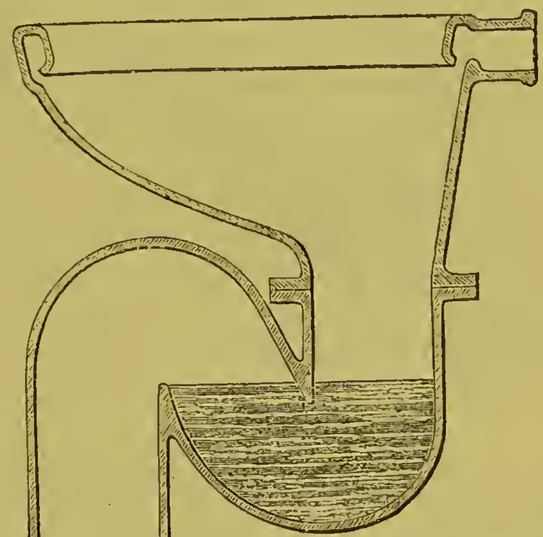


Fig. 77.—Patent Rim-flushing Basin.

or without a trap, are not necessarily satisfactory, inasmuch as if a piece of paper, a shred of flannel, a lucifer match, or other foreign substance, happen to be caught between the plug and the sides of the outlet-pipe, a leakage is created which will waste the water, and in the event of the water-supply being intermittent may cause subsequent inconvenience from the absence of water in the service cistern. In the same way a valve closet is open to the objection that the india-rubber seating on the valve is liable to let the water leak out of the basin; and, moreover, this india-rubber, after a while, needs renewal—not a very difficult matter certainly, but an inconvenience nevertheless.

The kind of apparatus which, on the whole, is most free from objection is that in which every part is formed of glazed stoneware; no india-rubber or metal-work of any kind being needed. In closets of this kind the trap is a permanent one, comprising merely a bent pipe, somewhat in the form of the letter S. If this trap, being a separate piece of stoneware, is wholly below the bottom of the basin, as in Fig. 76, it presents the objection that no water will stand in the basin itself, and thus the sides of the basin soon get fouled, and the way this kind of basin is usually

flushed, by a spiral flow of water, is very imperfect. These objections, however, are obviated with tolerable success by arranging the outlet of the basin in such a position as ordinarily to receive the deposited matter before it can foul the sides, and by means of a good flush of water from the entire rim of the basin the latter is generally kept clean and sweet. This kind of basin (Fig. 77) is commonly known as the patent "rim-flushing" basin; but another patent basin is made (Fig. 78) in which the trap, with the basin, is formed of stoneware all in one piece (which is an advantage), and is so arranged that, the basin itself forming, as it were, one arm of the trap, the level of the water is considerably above the bottom of the basin, thus tending to preserve the cleanliness of the basin, and to afford ready means of access to the trap; while by means of a vigorous and well-directed flush of water, the contents of the basin in this apparatus are always rapidly removed.

Another kind of basin is that belonging to what is known as the patent "wash-

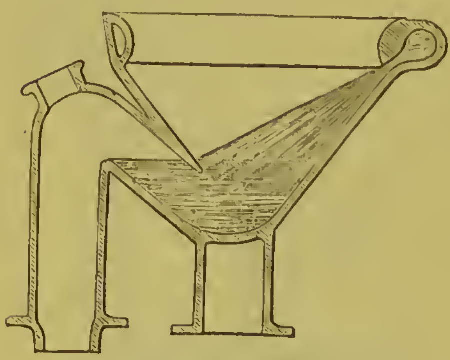


Fig. 78.—Patent Basin.

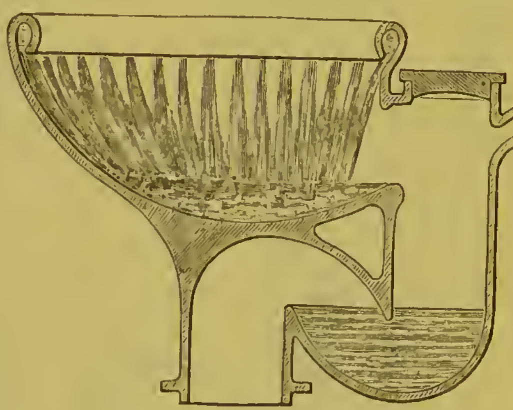


Fig. 79.—Patent Wash-out Basin.

out" closet (Fig. 79), in which the outlet from the basin is not at the bottom but from one side or at the back, and the flush of water is from the rim, but directed principally from opposite the outlet, so as, by its force, to "wash out" the basin. This kind of basin always contains a small quantity of water, though ordinarily not as much as could be desired, and if the flush be sufficient and properly directed it cannot fail to answer its purpose effectually. This apparatus, like the one last described, has no metal-work of any kind about it, being all composed of glazed stoneware, often all in one piece, and is capable of being easily kept perfectly clean and sweet. It, moreover, allows the contents of the basin to be readily inspected.

In the several closets last referred to, in which the trap is a permanent one without any absolute obstruction, it is not generally necessary to provide an overflow-pipe, because any continuous running of water can pass freely away. In the valve closet, however, an overflow-pipe is a necessity; but it is highly inexpedient to connect it with the soil-pipe immediately below the valve, as is frequently done. The overflow-pipe, acting as a warning-pipe, should either discharge in the open air outside an external wall, or the surplus water should be conveyed away by the waste-pipe from the safe beneath the closet apparatus.

In almost all the best kinds of water-closet apparatus, one of the most important points to be attended to is its connection with the soil-pipe. If this be neglected, and any defect is allowed to exist at the point where the base of the

apparatus is attached to the branch leading to the soil-pipe, there will probably be escape of drain-air direct into the house. Hence special precaution ought to be taken to make this junction perfectly air-tight. The plan most commonly adopted is to turn the lead of the branch-pipe over on to the floor, or lead safe, already described, and to bed the outlet of the water-closet apparatus thereon in red-lead putty. But inasmuch as the apparatus is usually rather heavy, and the space in which it is fixed generally very contracted, it frequently happens that in placing it over the mouth of the branch-pipe the putty gets displaced, and a faulty joint is the result. Two or three contrivances have been devised to obviate the possibility of defect at this point; but one of the best and simplest is to spread out the mouth of the branch-pipe to receive the base of the apparatus, and then fill in with red-lead putty, and dress the lead well over the flange near the base (Fig. 80). Another method is to bed the flange on a ring of india-rubber (Fig. 81); but, inasmuch as this material, though excellently adapted for the purpose when new, undergoes certain changes in its condition in the course of a few years, and especially if subjected to continued low temperature, when it becomes hard and brittle, it is doubtful whether it can be relied on for a permanently safe joint.

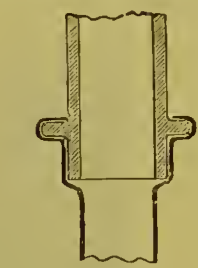


Fig. 80.

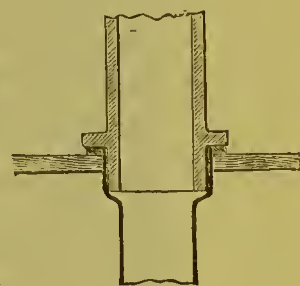


Fig. 81.

Another point deserving of consideration by every one about to fix a new water-closet apparatus is the arrangement of the seat and the enclosure of the apparatus. The apparatus is usually fixed and enclosed so that in course of time a vast amount of dust and dirt accumulates beneath the seat, or, indeed, may have been left there by the workmen when the closet was built; and where the closet is used for emptying slops of any kind, it commonly happens that small quantities of liquid are allowed to splash over the top of the basin—not sufficient, perhaps, to run away, but to keep a certain amount of permanent dampness on the floor of the space beneath the seat, and to give to the entire closet a constant smell. It would go far to promote cleanliness and prevent this smell if the seat enclosure were wholly dispensed with, and the floor, with its carpet or oil-cloth, were continued entirely under the seat. In the case of all the best kinds of closet apparatus, comprising merely a basin with syphon trap beneath—all in one piece of glazed stoneware—there would be no eyesore in such an arrangement, while every nook and corner would be visible and subject to the frequent application of the broom and duster (Fig. 82). Of course, a narrow wooden border could be formed on the upper edge of the basin, to serve as a seat, and also a lid, and some modification of the ordinary pull-up handle would be necessary to bring the flushing apparatus into action; but this could easily be effected by arranging the requisite wire connections somewhat in the fashion of an ordinary bell-pull. This, moreover, would have the advantage that there would be no sunk dish in the seat for the pull-up handle, which always allows dust and dirt to accumulate and is difficult to clean.

In determining the position for fixing the apparatus in a water-closet, it is obviously desirable to place it so that ample light from the window in the

day-time, and from the gas-bracket at night, shall fall upon the seat and into the basin.

Much has been said in the preceding few pages about the sweetness of the water-closet; and although the kind of apparatus that may be adopted will have an important bearing on the condition and wholesomeness of the air in the closet, it will readily be perceived that, even with the best kind of apparatus, constant personal attention is necessary in order to secure perfect cleanliness and sweetness. If, as frequently occurs, the precaution of effectually flushing out the basin immediately after the closet has been used be neglected, a very few days will suffice to make the basin so foul as to emit an unwholesome and offensive smell. Even if the closet be properly used, the basin will still need cleansing beyond what it receives from the regular flush of

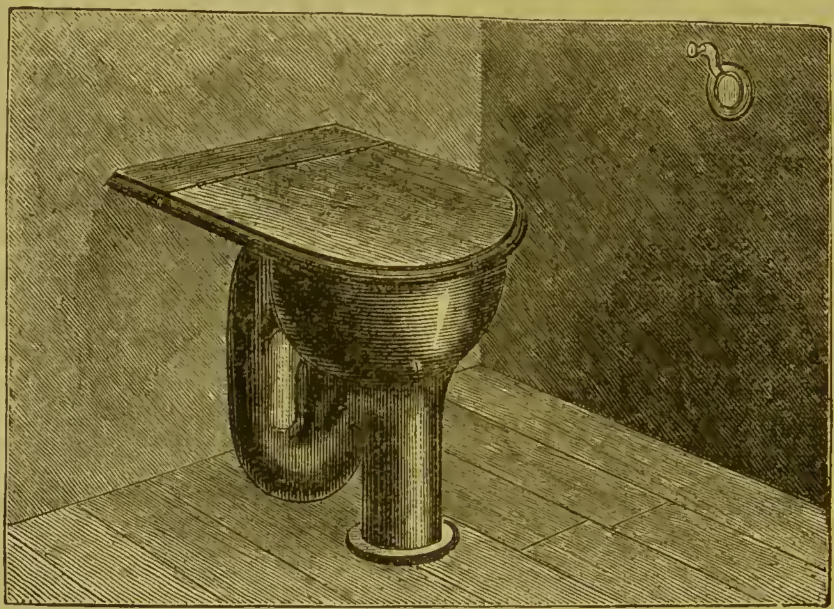


Fig. 82.—Closet without Enclosure.

water. In fact, wherever there is a water-closet it should be somebody's special duty to periodically rinse out the basin thoroughly with a brush kept for the purpose. The brush should be worked into the trap as far as possible, and likewise all round the upper part of the basin, the water being allowed to run through the basin while the brush is being used. This process, which is scarcely less essential than the daily rinsing of bed-room crockery, should ordinarily be done at least two or three times a week; and the brush may either be hung up just outside the water-closet window, or, if that be too exposed a position for it, a special can should be kept for it in the housemaids' closet, and in which it may be carried from one closet to another.

For more effectually securing the sweetness of water-closets, an ingenious contrivance is sometimes adopted for mixing a small quantity of some disinfecting fluid with the water in the basin every time the closet is used. Although this little contrivance is not without its advantages, inasmuch as it may tend to remove the smell which necessarily exists immediately after the closet has been used, it is nevertheless doubtful whether it can be regarded as in every way a desirable appendage to a closet. It is obviously an additional complication to the apparatus, and in this

particular is clearly undesirable. Then it needs periodical replenishment with disinfecting fluid, and this again is a difficulty; and, thirdly, the employment of such a contrivance recognises an improper condition of apparatus without effecting a remedy, but merely acting as a palliative. The more satisfactory way of preventing the atmosphere of a water-closet from permanently becoming offensive is to adopt a good and simple apparatus, and take care that it is kept perfectly clean, not only in the basin and trap, but outside and beneath the basin, and on the seat.

Various contrivances have been invented for regulating the quantity of water used in flushing water-closets in order to prevent waste. This is a rather important point wherever water is at all scarce, or where it is laid on intermittently to the cisterns of a house. Some of these contrivances take the form of an intermediate or flushing cistern, holding the requisite quantity (usually about two gallons) of water for each flush, which thus serves the double purpose of supplying a given quantity of water and of separating the closet apparatus from direct connection with the general service cistern. Other kinds of regulators or water-waste preventers consist of valves variously arranged, which, with easy adjustment, allow only a given quantity of water to pass through them each time the closet apparatus is emptied. The intermediate or service-cistern is the most common form of waste-preventer, and consists of a cistern, or box, holding only the requisite quantity of water for one flush, and supplied by means of a small pipe from the main cistern with an ordinary ball-cock, so that each time the water-closet basin is emptied the entire contents of this cistern or box are discharged by a syphon-pipe, or otherwise, and the ball-cock is immediately set in action to refill the cistern.

The quantity of water allowed by the regulations of the London water companies for one flush is limited to two gallons. This quantity, even under the most favourable circumstances, is small enough, and, in fact, rarely suffices for the effectual removal of the whole of the contents of the basin beyond the trap immediately beneath it, for which it is necessary to flush the basin a second time. In the case, however, of a closet in an upper storey, with a considerable length of soil-pipe beneath, it is wholly inadequate for flushing both the basin and the soil-pipe. A second charge of the flushing cistern ought always to be used, in order to flush the soil-pipe; but as the majority of people are not in the habit of taking this precaution, it would be of great advantage were the ordinary quantity of water for each flush considerably increased, or, at any rate, made three instead of only two gallons.

Of sinks, there are different kinds for various purposes. Thus, scullery sinks are provided in connection with the kitchen offices, and are used for washing and preparing vegetables, and for washing the utensils used in cooking. Pantry sinks are usually arranged for washing plate, glass, and the other more delicate articles used at meals. Housemaids' sinks are fitted up for use in connection with bed-room and toilet services; while the ordinary slop-sink is used for emptying all kinds of slops.

The scullery sink is the most common sink, inasmuch as it is necessary in every kind of house, of whatever size. Wherever cooking goes on, whether there be a distinct scullery or not, one sink at least has to be provided. Wherever space will permit, a scullery should contain two sinks—one for washing the various plates, dishes, and other food utensils in, and the other for cleansing vegetables in, preparatory to cooking them and serving them up. The sink for washing the articles used in cooking should be of such materials, and so formed, as to allow of its being readily

cleansed, otherwise it is liable, in careless hands, to get greasy in the angles and corners. The best kind of sink for this purpose is formed of glazed stoneware, the angles and corners being carefully rounded, so as to be easily cleaned. Scullery sinks, however, are most commonly formed of fine-grained sandstone, chiefly from quarries in the neighbourhood of Bradford, Halifax, and other parts of Yorkshire. The vegetable sink may conveniently take more of the form of a trough. It is usually deeper than is requisite for the washing-up sink, and, though occasionally formed of glazed stoneware, is more frequently formed of slab-slate, which serves the purpose very well. Both these sinks should have ample waste-pipes, with a sufficient slope towards the outlet, which should be protected by a fixed grating. If the grating be not fixed it will continually be removed, in order to get rid of the waste water and refuse more rapidly; but inasmuch as the grating is expressly for preventing a quantity of solid matter from being carried down the pipe to the drains, it ought to be permanently fixed. The orifices in the grating should be of an aggregate size equal at the least to the sectional area of the waste-pipe itself. This is an important point, often overlooked by the plumber.

The pantry sink being intended for washing more delicate articles in than the scullery sink, is generally formed of wood and lined with lead, the latter material being less liable to damage glass, china, and silver than stone or earthenware. If the water-tap over the pantry sink be furnished with a piece of india-rubber tube three or four inches long, it will be found to prevent much chipping and breakage of glass and china. All the sinks above referred to should have straining-boards at the side, grooved and slightly inclined, so as to let the water run towards the sink.

Housemaids' sinks, generally fixed on the upper floors of houses, being chiefly used for emptying and rinsing wash-hand basins and chamber utensils, are ordinarily formed of wood and lined with lead, as being least liable to damage crockery. It is important in these sinks to have a plentiful supply of water immediately over them, otherwise, unless they have exceptional attention, they are apt to become foul and offensive with the constant emptying of soapy water and slops. Indeed, these sinks need frequent periodical cleansing, however perfect and ample the supply of water to them may be. In all lead-lined sinks it is useful to insert a strip of bevelled wood beneath the lead along the angle of the wooden sink, in order to splay off the angles and prevent the accumulation of dirt there. It is important, moreover, in fixing any kind of flat-bottomed sink, that it should have a good fall towards the outlet, so that all water emptied into the sink should flow at once to the outlet. Some sinks, used merely for emptying slop-water, are made of enamelled iron, more in the form of a deep basin with the outlet at the bottom.

The outlet-pipe from the above-mentioned sinks, which should discharge visibly in the open air, should be of ample size—two inches, if practicable—and the shorter it is the better, as there are greater facilities for keeping a short pipe clean than a long one, and the inside will inevitably get coated with matter which in course of time may become offensive. Hence tho position for the sink will have to be determined by the position of the outlet from the waste-pipe.

A trap is generally necessary in the waste-pipe from a sink, and, indeed, in all wasto-pipes; for not only does the interior of such pipes got foul after more

or less use, but the gully or channel outside that receives the discharge from the waste-pipe is also liable to become offensive unless it receive frequent attention, and if there were no trap in the waste-pipe, the smells from the interior of the pipe or from the gully or channel would, under certain conditions, be drawn into the building. As a rule, a waste-pipe should not only be as short as possible, but it should also be easily accessible at the outer end, so as to allow of its being periodically cleansed by means of a brush being passed into it. The trap in the waste-pipe should be of the simple S form, and furnished with a brass screw-plug, in order to afford access to it for purposes of cleansing it and removing obstacles such as pieces of flannel, hair, stumps of lucifer matches, &c., which frequently get into the pipe. The trap should always be formed in the course of the pipe itself, the continuity of the circular bore being carefully preserved. Excellent cast lead pipe-traps of various diameters, with suitable screw inspection-holes, are manufactured expressly for the purposes above referred to.

The "slop-sink" proper differs from other kinds of sinks, inasmuch as it is intended to receive solid matter as well as liquids. It in fact resembles in some important particulars the ordinary water-closet apparatus, though it is not usually provided with any complicated flushing contrivance, and does not ordinarily hold a permanent quantity of water in the basin. The chief difference is that it is fixed at a higher level than a water-closet apparatus, in order to be more convenient for emptying vessels into it. It is furnished, moreover, with a tap above it of sufficient size to afford a copious supply of water for rinsing out any vessel that is held under it. The best kinds of slop-sink are those in which the basin or receptacle is formed of or lined with lead, or of iron with a porcelain enamelled surface, the trap beneath being an ordinary syphon or S trap of circular section not less than three inches diameter (and furnished with a screw-plug for access to it), connected with an ordinary soil-pipe in the same way as a water-closet apparatus. These sinks are chiefly used in hospitals and other public institutions where bed-pans and commodes have frequently to be emptied; but they are often useful in ordinary houses, though until recently not common.

It must be remembered that in emptying quantities of waste and slop-water into a sink or water-closet basin, it may be done so carelessly that the water cannot flow away fast enough, and the liquid is liable to flow over the sides and on to the floor beneath. In order to meet such contingencies and to prevent the ceilings and other parts of the building beneath from being damaged by the water, it is usual in properly-built houses to form what is known as a "safe" beneath every water-closet apparatus, slop-sink, &c., in the same manner as beneath the bath. This consists of a shallow tray, generally of lead, with an outlet-pipe passing through an external wall, where it is either cut off about six inches away from the outer face of the wall, so as to serve as a warning-pipe to show when anything is wrong, or it discharges in the open air over some channel or gutter. When a water-closet basin is likely to be used for emptying slops, it is useful to arrange the seat, as well as the lid, so as to be lifted up when any vessel is being emptied there; and if the seat is enclosed in the usual way, the top of the basin may be dressed over with lead, arranged so as to prevent splashing over on to the floor beneath, in which case the safe above described would not be so necessary.

CHAPTER XIV.

FITTINGS.—COOKING APPARATUS.

Ancient Cooking-ranges—Arrangements for Roasting—The Modern Close Range—Modern Open-Fire Ranges—American Stoves—Other Close Ranges—Ranges for Cooking by Gas.

Of the many important fittings of a house—be it a palace or a cottage—the cooking-range or apparatus is clearly one of the most important.

The kitchen itself has from very early times, as we see from the ruins of many an old priory, always claimed much attention, and the appliances for cooking the food obviously constitute the most important objects in the kitchen.

In former times there was probably little difficulty in determining what form of cooking-apparatus to adopt; but in the present day one is bewildered with innumerable advertisements and descriptions of different kinds of cooking appliances, each of which claims to be at once the most efficient, economical, simple, convenient, cleanly, and, in every way, the most desirable. Thus any one nowadays having to rearrange a kitchen, or to erect a new one, is placed in a very difficult and responsible position, and this difficulty, moreover, is enhanced by the fact that some one else will have the practical working of the apparatus, in whom will, very likely, rest its success or otherwise.

In early times the cooking-stove was most probably the open range, formed by brick jambs and back, with horizontal bars built across the front, and of considerable depth from front to back, for the purpose of burning wood. The meat to be roasted was supported on horizontal spits, revolved by hand in front of the fire. This form of range has been improved upon from time to time, both in its construction, and in the method of revolving the meat. Cast-iron came to be used for the jambs, and coal being substituted for wood as fuel, it became necessary to make a considerable reduction in the depth from front to back. In order to still further economise this valuable fuel, means of contracting and expanding the width of the fire according to the size of the joints, or the number of viands, capons, &c., that had to be "spitted" or suspended before it, were introduced, and for this purpose cast-iron sliding cheeks, with the requisite winding-pinions, rack-attachments, and winch-handles, for setting them in motion, were provided. So far the roasting apparatus was now a complete machine, and is used in exactly the same way to-day as it was when originally introduced. The arrangements for supporting and turning the meat, however, required improvement, and dogs, springs, the motive-power of water, the motive-power of the ascending current of heated air in the chimney, and occasionally steam, have severally been used to effect this purpose. With the exception of dogs, they all and each exist in the present day, for the same purpose, in numerous modifications, from the spring bottle-jack, which turns its modest eight or ten pounds of meat, to the huge smoke or water-jack, ten or twelve feet wide and more, turning regularly its five or six hundredweight of meat at a time, and occasionally even more than that. Some of these methods of turning the meat necessitated the use of long horizontal spits passing through the joints to be roasted, and supported at each end upon hooks

or arms, either as part of the range itself, or, in large establishments, fixed to the chimney-jambs at varying heights, thus allowing several spits to be in use at the same time. The motion is conveyed to the spits by chains working from a wheel on the spindles of the jack.

The well-known and useful bottle-jack is generally suspended from a small crane fixed to the facia of the chimney-piece, the meat being hung vertically, and this system has of late years called into requisition additional motions to the smoke-jack besides the old spit motion, thus considerably increasing the machinery; and it is now not unusual to find smoke-jacks not only having the simple spit motion, but also two, three, four, and even six dangles or vertical hanging motions.

Besides the arrangements above described for roasting, the ordinary kitchen range generally had "hobs" at the sides, on which saucepans and kettles could be placed which did not require to be actually over the fire, while revolving "trivets" were provided for supporting them over the fire. These ranges, even though the space behind the bars was shallow, held a vast quantity of coal, and in course of time the large consumption of fuel was made to maintain a supply of hot water, by a boiler being fixed behind and at one side of the fire. The next improvement was to arrange the boiler so as to be self-feeding, and thus obviate the inconvenience that was continually recurring of the boiler cracking in consequence of the cook omitting to keep it permanently filled with water—an operation that had previously to be done by hand.

In the last thirty or forty years many improvements in the details of construction of cooking-ranges have taken place. The crude contrivances of the earlier part of the present century are disappearing, and much skill and ingenuity have been exercised to bring into use what is now commonly known as the close range, or "kitchener." This apparatus may be briefly described as comprising a comparatively small fire-box, with an oven on one side, a boiler on the other and at the rear, and a hot plate on the top. By means of a set of three dampers in the chimney-flue, the heat may be directed either about the oven or about the boiler, or the draught may be directed exclusively through the fire, and the fire may be either shut up in front or open for roasting. The kitchener is certainly an improvement in many respects upon its predecessors, but, nevertheless, in the hands of the modern cook it is capable of consuming an amount of coal which, compared with the size of the fire-box, is simply surprising. The rapidity with which, by means of drawing out the dampers or neglecting to close them, it devours fuel at all times of the day, no matter how much or how little cooking is going on, results in a waste of coal which, to the economical housewife, is appalling; and this waste is often increased by the use of a quick-burning coal, most ill-adapted for such a fire. There is, as a rule, more comfort, convenience, and cleanliness in the careful use of a kitchener, or close range, for cooking purposes of moderate requirements than the old-fashioned open fire-grate, but it can hardly be said that the kitchener is, in practice, very economical. It is doubtless true that it will burn cinders; but cinders are not so easy to obtain as coals, inasmuch as the latter are generally near at hand, while the cinders have to be sifted—an operation that involves some trouble, and causes a considerable amount of dust and dirt. On the other hand, however, it has

been computed that owing to the use of open fires in private kitchens, as much as nine-tenths of the heat produced in cooking operations is lost, one-tenth only being really utilised in cooking.*

The two kinds of ranges above described—namely, the open one and the close one—are now, with numberless modifications of detail, the standing types of cooking-ranges in which solid fuel is used. In the "open-range" class may be included all those ranges which have an open-top fire for roasting, and an open chimney, into which the smoke ascends direct from the top of the fire. In the "close-range" class may be included all those ranges which have a closed top, covered by a plate, and a closed chimney, into which the smoke ascends by means of conducting flues, and is delivered over the plate closing in the chimney opening. In this class may likewise be included all the modern American close cooking-stoves, some of which are so small as apparently to be mere toys, but which for many purposes are very useful.

The open-fire ranges may be divided into two sorts—those called self-acting, which are fitted with flues passing round the oven and round the boiler respectively, each under control by a damper, and those not self-acting, which have the fire simply placed against the boiler and oven, and in which the heat is not controlled by dampers.

The simpler form of range without flues is usually made in small sizes, and thousands of them are fitted all over the country in the cottages of the labourer and the dwellings of the artisan. This form of range, however, is again subdivided into numerous kinds, differing from each other in many details of more or less importance. Some have winding checks, to contract and expand the width of the fire; some have bars to fall down outside so as to form a sort of table, and some have bars to fall down both outside and inside; some have bars which, if they get broken, involve the entire renewal of the range, and in others the bars are removable and easily replaced; some have oven doors hung on the side, and in others the oven door is hung at the bottom, so as to fall down and form a table; some have fire-brick linings to the fire; some have a boiler; and there are some which always give satisfaction and others which are always unsatisfactory; for although there may apparently be so little difference between two different ranges that to the ordinary observer they would be identical, the one would be a veritable treasure, while the other would be a constant annoyance; the one may depend very little on its setting, and the other needs some particular attention to the way it is fixed in position.

The self-acting form of this range is made in sizes for fireplaces six or seven feet in width, with a roasting fire three feet wide, a boiler behind that will serve hot water all over the house, and a self-acting oven that is heated by the flue passing round it and beneath the "hob," which forms a convenient hot-plate. This range, if properly constructed by taking the flues which heat the oven, hot-plate, and boiler from the lowest corner of the fire next the oven, is a very economical one, and requires a very moderate quantity of fuel in order to keep the baking and boiling arrangements in proper working order. It has been largely adopted, in a more or less perfect form, all over the country in the houses of the more well-to-do, and although it may be said to have been, to a certain extent, superseded by the

* Count Romford.

introduction of the close range, it will probably still command favour with large numbers, who, whether from prejudice or otherwise, like their roasts roasted and their baked meat baked. This range is usually associated with a smoke-jack, and thus forms a very complete apparatus for cooking for a considerable household, possessing, as it does, a roasting-fire that may be reduced in size at pleasure by the winding cheek, a perfect baking-oven, a hot-plate hob over the oven, hot water for all purposes, and a cheerful appearance with ease of management.

The close-fire ranges do not divide themselves into distinct divisions like the open ranges. They are each and all in their structure stoves, having flues through which the flames are made to pass in order to heat the hot-plate, oven, or boiler, as the case may be, and each separate flue is furnished with a damper. The simple form suitable for the home of the agricultural labourer and artisan is of the inexpensive American cooking-stove type. Of these, the varieties are very numerous. They usually comprise an oven and hot-plate, heated by the smallest possible fire, and with no means of roasting. These cooking-stoves generally need very little setting, being merely placed in their position in the chimney-opening, and in this respect they have the advantage that the whole space about them can be finished with tiles or otherwise, so as to prevent the harbouring of black beetles and other vermin.

The larger and more complete form of close range is fitted with one or more ovens and a boiler, from which hot water can be supplied for all purposes. The fire is usually situated centrally, and is of only sufficient size for a moderate joint to be roasted in front of it. From the fire, flues branch off to the right and to the left, passing under the hot-plate top, and surrounding the ovens, also under the boiler and up the back, and each of these flues is furnished with a damper. The whole of the chimney-opening is enclosed at the top, a rack being fitted beneath the enclosure for keeping plates and dishes hot, and the flues carried up to the chimney above this enclosure. One or both of the ovens is ventilated, and it is asserted that the oven then becomes a roaster, and that articles placed therein are roasted, and not baked. It would be more correct, however, to describe them as baked in a ventilated oven.

These close ranges are sometimes made of considerable size—twelve to fourteen feet in length—by a repetition of ovens right and left. In houses of moderate size they are largely used, and are much liked by cooks because of their cleanliness. They offer some advantages, one of which is that they are at once self-contained, and will do a considerable amount of work with the one fire; but to do this they are at the same time self-destructive, and consume a somewhat large amount of fuel; for the fire, being closed up, partakes of the character of a furnace, and becomes so fierce as not unfrequently to melt the bottom and the front bars, and to create danger to the house from the usually insufficient thickness of brickwork and the proximity of woodwork about the lower portion of the chimney-flue. Another objection to the close range is that when anything boils over, or gets spilt on the hot-plate, the smell of burning is produced more rapidly than it can be carried away, and speedily pervades the house. A further difficulty in connection with the ordinary close range is that it possesses no means for reducing the size of the fire, so that whether there be much or little cooking going on, to allow of its being done effectually the fire-chamber must be full, or the cold air getting into the flues will

altogether destroy the action of the stove, and keep it at an unduly low temperature.

It is true that in recent years many ingenious contrivances have been invented to reduce the size of the fire when not actually in use for cooking, and likewise to make the fire an open or a close one, so that the cheerfulness of the open fire may be associated with the requirements of the close one. These and similar improvements that have been introduced in the close range, however, so add to its complications that what with two or three dampers to the smoke-flues, dampers to the ventilated oven, and the arrangements for reducing the size of the fire, often necessitating the removal of some of the front bars and the folding doors into the smoke-chamber, and the removal of part of the hot-plate to make it an open fire, it becomes a really intricate piece of mechanism, requiring more than ordinary intelligence to understand and manage.

The cooking arrangements referred to in the foregoing pages meet most of the ordinary requirements of the cottage, the artisan's dwelling, the villa, and the town house of moderate pretensions, the main difference being in the size of the range. In town and country mansions, however, much more may be wanted, and the range is then supplemented by various auxiliary appliances. Some of these may be boiling-coppers, set in brickwork or iron-cased, for hams and large joints; also a separate hot-plate with separate fire, for use when the hob of the grate will not take the requisite number of sauce and stew pans; and these, with the necessary hot-closet or the fire-screen arranged for keeping plates and serving-dishes hot, will then be found sufficient for most of the ordinary large town houses and country mansions. In the yet larger palatial residences, however, where the offices for preparing food are necessarily very extensive, there is frequently a series of charcoal stoves, or, if it is the fancy of the "chef de cuisine," gas stoves, gas being either brought from some public supply, or made on the premises by some of the modern ingenious inventions for the purpose. Then there is the special stove for the immense stock-pot which is constantly at work day and night when gas is in use; also the "bainmarie" pan, worked either by fire, gas, or steam—generally by steam in large establishments—which comprises the hot bath, in which are kept the sauces and soups ready for service. A hot-table may also be provided for "dishing-up" upon, with its hot-closet beneath for the chef's own immediate use. There may likewise be distinct appliances—steamers and the like—for cooking vegetables, &c. in; also a special double oven for pastry.

The use of gas for cooking purposes has been subject to so much improvement in recent years that it is not unlikely before long to become common in most kitchens. In many houses where it has been in use for some years it serves chiefly as an auxiliary means of cooking when extra work is required, or during very hot weather, when the kitchen gets so hot as to be almost unbearable, the range in the kitchen being the one in general use.

A serious practical drawback to the gas cooking-apparatus in moderate houses as an auxiliary is that, in the hands of the modern cook, it fails to effect the economy that is expected of it, inasmuch as while good cooking is being performed by it with ease and cleanliness, the kitchen fire is still kept going—often with all the dampers carelessly left drawn out—consuming as much coal as if the gas stove were not in use at all, and this perhaps merely to boil water for washing up the cooking-utensils,

plates, and dishes, &c., after the meal. This is obviously an extravagant way of going to work; but until a cheap gas stove is devised that, without extra gas, will boil plenty of water while it is performing its task of cooking, it is to be feared the gas cooking-apparatus will not take a leading place in the kitchen of the ordinary house.

In the gas cooking-apparatus the gas is used either by burning it pure as it issues from the burners or the orifices in the gas-pipe, or by causing it to mix with atmospheric air just before it reaches the point of ignition. In the latter case the gas is burnt with almost perfect cleanliness, without any smoke, and with only a blue flame practically devoid of light. The process is conducted either by the flame actually impinging on the cooking-utensil, or the heat may be directed on to the food by reflection, or by the jets of gas being just beneath and around the food.

The cheapest form of ordinary gas cooking-stove is the portable one, which contains merely a ring of burners, with a cast-iron stand over it to support a kettle, saucepan, or frying-pan. The apparatus has a handle, to which an india-rubber pipe is attached for supplying it with gas, and the air is mixed with the gas by means of holes in the handle. Although this stove is intended for the cooking to be done over the flame, it is possible, by the reflected heat from it, to cook bacon, eggs, and even chops beneath the flame.

If, however, cooking otherwise than by boiling is habitually required, a larger and different kind of apparatus would be found more convenient. This consists of a sort of iron box, about twelve inches square and ten inches high, having a hot-plate with a central hole in it on the top, and a ring or row of gas-burners underneath, immediately beneath the hole. The space under the ring of gas-burners is fitted with a gridiron and pan, on or in which bacon, eggs, chops, steaks, and even chickens or small joints may easily be cooked by reflected heat while boiling is taking place on the top.

The kind of cooking-apparatus last described can be extended so as to be capable of cooking a large quantity of food. Thus, if the hot-plate on the top is enlarged to hold three or four rings of gas-burners, several saucepans can be in use at the same time, while the space beneath may be enclosed to form an oven for baking bread, pastry, &c., and beneath this again may be a space for roasting meat by arranging additional rows of gas-burners.

These cooking-stoves are made of plate-iron of various thickness, and inasmuch as this becomes very hot, and much of the heat is lost in the kitchen or room in which the stove is placed, to the inconvenience of the servants, an improvement has been introduced by which the interior of the oven and roaster is lined with fire-brick, which not only prevents the escape of the heat, but retains it, so that, after the gas is extinguished, there is sufficient heat left in the walls of the oven and roaster to continue the cooking for some little time longer. This kind of gas cooking-apparatus can be extended to almost any size required, and when of large size there is no difficulty in fitting it with an ample boiler for a supply of hot water. Many important institutions, hospitals, barracks, schools, clubs, &c., now use the gas cooking-apparatus to a very large extent, and it is alleged that while the economy of fuel and labour is considerable, the annual saving of food, by the prevention of waste, represents a large sum.

CHAPTER XV.

GAS AND MISCELLANEOUS FITTINGS.

Closets and Cupboards—Electric and Pneumatic Bells—Telephones—Gas-meters—Gas-pipes—Gas-regulators.

Closets and cupboards, as fixtures in and about the various rooms of a house, ought to be regarded as fairly good investment of capital, inasmuch as they invariably add to the attractiveness of a house by tending to obviate the necessity of acquiring sundry articles of furniture. Recesses in bed-rooms and dressing-rooms, when fitted with shelves, hanging rails, and drawers, make excellent substitutes for wardrobes. They have the advantage that no space is left behind them, as is the case in so-called movable furniture, which is often so cumbersome that it is never moved from one year's end to another, and which consequently allows an accumulation of dust and dirt behind it which ought not to be tolerated. The top may and should be level throughout, and covered with smooth boarding, to facilitate the frequent removal therefrom of all dust. The panels of the doors of these fixed wardrobes may with advantage be fitted with looking-glasses, which in many instances would do duty as cheval glasses. Recesses may also occasionally be fitted with seats. The window recesses can have seats forming boxes for linen, &c. In fact, no space ought to be wasted in a house, any more than in a ship, where every nook and corner is of necessity turned to some useful purpose. Another kind of recess may here be mentioned. In certain positions about a house, wherever there is a gas-bracket, it is usually convenient to provide a box of matches. It generally occurs that the matches are struck on the surface of the wall near the gas-bracket—unless, indeed, the patent safety matches are used, which ignite only when struck on their box—and this produces an untidy appearance, and should be avoided. If a small recess were made in the wall or partition wherever matches are likely to be required, and a suitable china or earthenware match-box were fixed therein, with a proper place in front for striking the matches on, it would greatly conduce to tidiness, while the extent to which such a recess could be arranged as an ornamental feature on the staircase, landing, or elsewhere, is almost unlimited. It could be of the simplest form, or it might be arranged somewhat as an adaptation from the stoup common in ecclesiastic Gothic architecture.

As regards means of communication from one part of a house to another, the most common is the bell with wire connections. In recent years, however, other contrivances have been largely introduced, and are found to possess certain important advantages. Thus, electric and pneumatic bells are free from the inconveniences so common with ordinary bells—namely, the stretching of the wires to such an extent as to involve difficulty in moving the bell sufficiently to make it sound. The mechanism of the electric and pneumatic bell, especially the former, is far more simple than that of the ordinary bell, with its innumerable wires, cranks, levers, &c., all of which are easily put out of order. The pneumatic bell is perhaps

more easily put out of order than the electric bell, on account of the risk of the tubing, or the india-rubber bag, immediately under the part which receives the pressure from the finger, being injured so as to let the air escape in the wrong direction, while the electric arrangement merely involves the use of a galvanic battery; but as the latter, when once put in operation, will continue to work for several years, and as the former is extremely simple, either of these arrangements is infinitely better than the old-fashioned wire-action bell.

The speaking-tube is another common mode of communication, and answers the purpose very well within a limited distance. It is, however, not wholly free from objection, inasmuch as it permits of general conversation in a room being overheard at the remote end of the tube—a circumstance not always to be desired.

The telephone—the most recent invention that has been put to practical use as a means of communication—is probably at present only in its infancy, in this country at any rate, compared with what it will doubtless be in the course of a few more years. It is already in use in Canada and the United States to a much greater extent than in England. Thus Dr. Mouat tells a story that, when recently at Toronto, he received an invitation to spend an evening at the suburban house of a gentleman whose place of business was in that city. He had no difficulty in finding his way to the house—a few miles out of Toronto—before dark, but later in the evening he began to consider how he should find his way back to his hotel, there being no available vehicle at hand. His kind host, however, soon relieved him of his difficulty by desiring his daughter to communicate with the caretaker at his office in Toronto. By means of a telephone the latter was directed to engage a cab at the stand opposite the office door, and direct the driver to proceed to fetch Dr. Mouat, which he did in the course of about half an hour. In the same way telephonic communication may often be usefully provided between a gentleman's residence and his stables or entrance-lodge, as well as with his more remote place of business. Telephonic communication is also provided between police-stations and hospitals, in order that, on the occurrence of an accident of any kind in which persons are injured, the hospital authorities may be at once apprised, and prepare to receive the patients, or indeed send the ambulance to fetch them.

The position and arrangement of the gas-meter and gas-pipes in a house, like the water-pipes, is a matter that is frequently left, in a great measure, to the discretion of the journeyman gas-fitter. The position of the gas-meter, for example, instead of being where it can be constantly under observation, is generally either on some high shelf, or low down on the floor, in some dark and inaccessible cupboard in which numerous articles not in frequent use are stowed away. The ordinary householder usually regards the gas-meter with a certain amount of indifference. He feels that although it is intended to serve as a kind of check against his being charged for more gas than he has actually consumed, yet there is a degree of mystery about it that it would be useless for him to attempt to unravel; and that practically he is wholly at the mercy of the gas company, in whose interest alone the meter will keep its record. It is surprising that so responsible an instrument, and one which is to be found in almost every house and building, although in reality so simple, should be so little popularly understood. How many persons are there among our circle of acquaintances, for instance, who are in the habit of periodically examining the index of their gas-meter, to see that there is no undue

expenditure or waste of gas, and that they actually are supplied with the quantity for which they are charged? These same people who neglect to examine the gas-meter would, nevertheless, deem it a matter of importance to look into their weekly or monthly bill from the butcher, baker, or other tradesman, in order to satisfy themselves that they were not going to pay for what had not been supplied to them.

Gas-meters are of two kinds, one being known as the *wet* meter and the other as the *dry* meter. The wet meter is so called from the fact that it has to be partly filled with water, in order to control the admission of the gas by means of a floating valve, while the dry meter is complete in itself without the aid of any liquid. The wet meter consists of a cylindrical case standing on a suitable foot, and within the case is a revolving drum divided into three or four compartments, somewhat resembling the buckets of a water-wheel, into each of which the gas is introduced one after the other, and as one compartment becomes charged with gas from the main, it passes on, making way for the next, and delivering its contents to the service-pipe. Each compartment is made of a known specific capacity, such as a third or a quarter of a cubic foot, and as the compartments revolve, they record on the index-dial by means of a system of cog-wheels the exact amount of gas that has passed through the meter.

The dry meter, generally shaped more like a square box, is constructed upon the same principle as a pair of bellows; and when they are expanded a quantity of gas enters at an inlet, while on their being compressed the gas is expelled at an outlet. The capacity of the bellows, or flexible chamber, being known, the quantity of gas passing through it can be registered by a system of cog-wheels, as in the wet meter. In the dry meter these bellows, or flexible chambers, are in duplicate, in order to secure regularity in the continuity of supply of gas to the service-pipes.

The wet meter is commonly preferred before the dry meter, as it is held by some to be more durable and more reliable than the dry meter; but as a set-off against this alleged advantage, it has to be borne in mind that if fixed in an exposed position the water in the meter may get frozen in very cold weather, and thus stop the supply of gas, while if fixed in a warm place it will evaporate and pass into the service-pipes in the form of a vapour, and there become condensed and interfere with the free passage of the gas, thus producing a flickering or jumping flame. The inlet for the water will be found just below the index-dials, and the outlet for surplus water near the bottom of the front, each being stopped by a screw-plug. It may be useful to remember that a small quantity of glycerine mixed with the water in the wet meter in cold weather will generally prevent the water from freezing.

The index of the gas-meter is a simple arrangement of dials for recording the quantity of gas that has passed through the meter. It comprises a certain number of dials, according to the size of the meter. The ordinary wet meter for ten lights has usually three dials, one recording the number of units of cubic feet—that is, up to nine; the second, the number of tens of cubic feet up to ninety; and the third the number of hundreds of cubic feet, up to one thousand. The index of the wet meter has the word "cents" written upon it above the dials, thus indicating that the units mark *units of cents.*, or units of *hundreds*, of cubic feet; the second dial

marks *tens of cents.*, or *thousands*, of cubic feet; while the third dial marks *hundreds of cents.*, or *tens of thousands*, of cubic feet. A small index is usually provided for recording the passage of small quantities of gas, in order to test the accuracy of the meter, or whether any leakage of pipes is taking place on the premises. When the hand on the first dial to the right ("units"), having made one revolution, stands at zero, the hand on the second dial ("tens") will be found to point to the figure one, signifying that *one* ten cents., or hundreds, of feet have passed through the meter. In the same way, when the hand on the first dial has made ten revolutions the hand on the second dial will be found to stand at zero, and the hand on the third dial ("hundreds") will stand at *one*, signifying that one hundred cents., or ten thousand feet, have been consumed. When the hand on the third dial has made ten revolutions, it indicates that ten hundred cents., or one hundred thousand, cubic feet have passed through the meter, and the system of record then automatically begins again. This sometimes may puzzle the amateur observer of a meter, but it is easily explained. If at a certain quarter-day the index, on being examined, shows that 98,500 cubic feet of gas has been consumed, and at the next quarter-day it shows only 1,700 cubic feet, the actual quantity that would have been consumed in the interval between the examinations of the index would be 1,500 + 1,700 = 3,200 cubic feet; in fact, had the index possessed a fourth dial, as found in large meters, it would have shown 101,700 cubic feet.

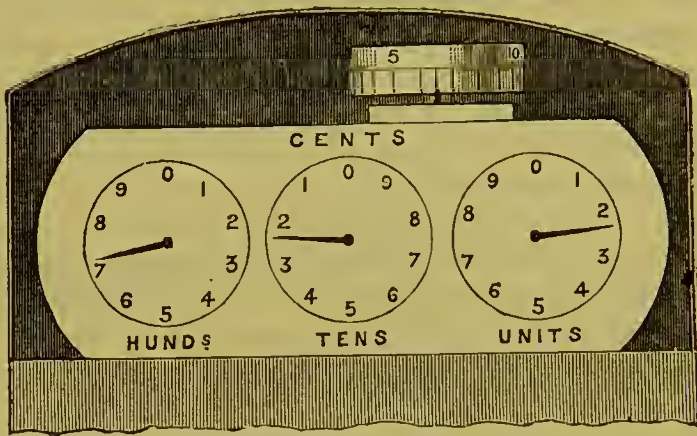


Fig. 83.—Gas-meter Index.

The piping usually adopted for laying on gas is of wrought-iron for sizes of half an inch in the bore and upwards, while for smaller pipes a composition of lead, tin, and antimony is used. These pipes should always be fixed in such a position that any escape of gas can easily be detected. If let into the wall, they are liable to be affected by various conditions, such as settlements, damp, chemical action, &c., which may produce leakage. If inserted in hollow partitions, a leakage of gas might be exceedingly dangerous. Where they have to simply traverse a hollow partition, it is a good plan to insert a larger pipe through the partition, and to lay the gas-pipe therein. It is difficult to avoid placing gas-pipes beneath floor-boarding, but when this is done, the boarding over the pipe should be screwed down in preference to being nailed, in order that the boards may more readily be removed for access to the pipe. A hole here and there about an inch diameter is very useful in the floor-boards over the pipe, in order to detect any escape of gas. They can be stopped with corks. Of course, any examination of these holes must not be made with a light of any kind.

Too much care cannot be given to the fixing of gas-pipes and fittings. The joints must be perfectly sound, and made so as to remain permanently sound. The

screwed joints in iron pipes should have thinned white lead rubbed well into the thread of the screw before being brought together.

With regard to the burners best adapted for gas-lighting, it may be premised that the quantity of light to be obtained from gas is dependent on various circumstances, such as the pressure of the gas at the point of issue, the size of the orifices of the burners, the temperature of the surrounding atmosphere, the quantity of air combining with the gas, the quantity of gas consumed, the form, dimensions, and materials of the glasses enclosing the flame,* &c. It would be out of place here to go minutely into all these several points of detail, but it will be useful to state that when gas is burned under excessive pressure, or with the orifices of the burner of restricted dimensions, it gives little or no light; and in proportion as the pressure is diminished so is the illuminating power of the gas increased, until arriving at the point where it is consumed to the greatest advantage.

In order to control the pressure, and thereby obtain the utmost advantage from the gas, various kinds of "regulators" have been invented. These regulators may be applied either to control all the burners on the premises, or only a portion of them, or separately to each burner. The regulator applied to each burner is held to be the most advantageous.†

Gas-regulators, like meters, are of two kinds—"wet" and "dry"—the simplest being the dry regulator. They are of considerable importance to the consumer, as it is said to be by no means an uncommon circumstance for a saving of from thirty to forty per cent. to be effected by means of the regulator, without reducing, but rather increasing, the amount of light; while infinitely greater purity is obtained in the atmosphere, owing to the completeness of combustion that takes place. Regulators, however, are not generally recommended by gas-fitters, there being little profit attached to them, and they tend to indicate any defect that may exist in the fittings. Gas-fitters have been known even to remove them, on the plea of their being unnecessary, or an impediment, but this should never be permitted without careful examination. Some so-called regulators are merely small vessels filled with tow, cotton, shot, or other similar material, which only obstructs the passage of the gas when the pressure is great, while it prevents a proper and sufficient supply when the pressure is weak. Such "regulators" utterly fail to fulfil the desired object, and are neither economical nor advantageous.

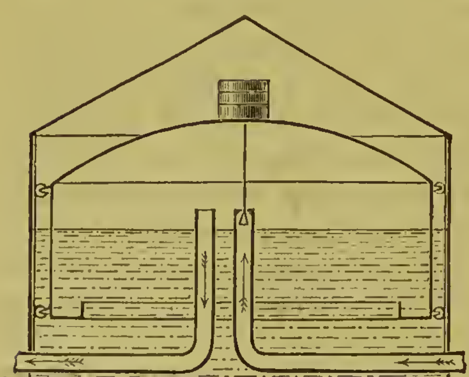


Fig. 84.—Patent Wet Gas-regulator.

The "wet" regulator (Fig. 84) comprises a sort of lightly-constructed bell, arranged in a metal case partly filled with water, to rise and fall according to the pressure of gas beneath it. Under the bell, and rising above the level of the water, are the inlet-pipe and the outlet-pipe for the gas. Into the mouth of the inlet-pipe is suspended from the top of the bell a conical plug, and as the bell rises with increase of pressure of gas the conical plug obstructs the entry of the gas. The lid of the case is made to open, in order to allow the bell to be weighted according to the required pressure.

* "The Manufacture and Distribution of Coal-gas," by W. Richards, C.E. † Ibid.

The "dry" regulator (Fig. 85) acts in a somewhat similar manner to the wet regulator. It comprises a chamber containing a lightly-made diaphragm something like an umbrella formed of fine leather coated with some protective material, and having a short stick with a conical plug at the bottom. As the gas rises under this diaphragm, the latter ascends, and draws up with it the conical plug, thus

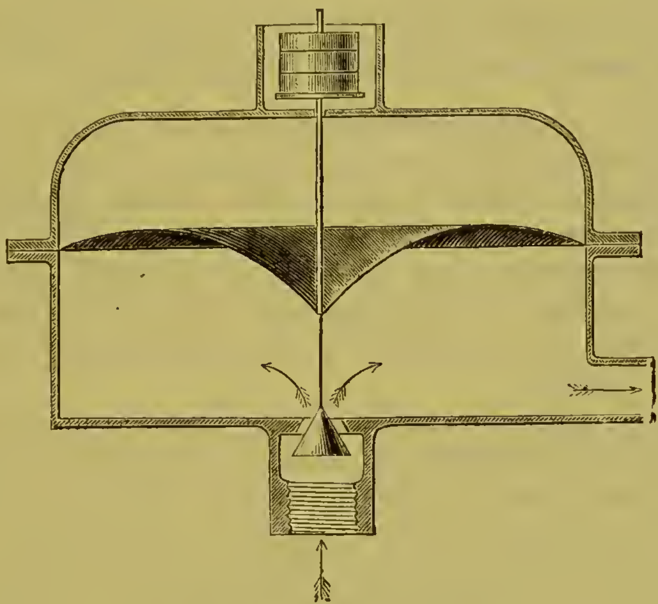


Fig. 85.—Patent Dry Gas-regulator.

reducing the size of the inlet orifice. An arrangement is made at the top by which the shaft to which the diaphragm and conical plug are attached can be weighted according to the desired pressure.

Another and convenient patent method of regulating the supply of gas to a house is by inserting into the pipe, immediately before it enters the meter, a stop-cock with a lever attached. The ends of this lever are in communication with a hand, resembling the hand of a clock, fixed on a dial. The hand is made to move by a key, and as it moves the stop-cock of the gas-pipe is turned so as to increase or diminish the amount of gas passing through the latter. The hand on the dial and the lever are so adjusted that as the former is turned so as to point to figures on the dial, these figures represent the number of burners which can be supplied with the apparatus in that position. Thus, if but two burners are required at night the hand is pointed to II., and no excess of pressure is possible. This is a very great advantage, not only in preventing the waste of gas, but in diminishing the probability of any escape through any weak point in the gas-pipes, which do not, under these circumstances, become exposed to pressure, and it has therefore a bearing upon health which is sufficiently obvious.

This regulator can be placed in any part of the house, and the entrance-hall is usually found a convenient position for it to be stationed.

CHAPTER XVI.

DWELLINGS FOR THE POOR AND ARTISAN CLASSES.

Over-crowding—Effects upon Health and Morality—Necessities of a Workman's House—Back-to-Back Houses—Plans for Labourers' Cottages—Public Lodging-houses—Small Blocks of Artisans' Residences—Larger Blocks and Peabody Buildings—Cottage-building.

The arrangement of a comfortable and wholesome house for the poorer classes of the wage-earning community, both in town and country, is a matter of national importance. If a separate house cannot be provided for a family, the head of which earns no more than sixteen to twenty shillings a week, that family must necessarily share a house with another family; and this leads to the system of lodging-houses, in which it is not by any means an uncommon occurrence for each room to be occupied by a different family, with the result of overcrowding and consequent offences against health and morality.

The rapid growth of large towns has, in many instances, undoubtedly had a most prejudicial effect upon the dwellings of the poorer inhabitants. It has often happened in towns where, owing to the development of some special industry, the population has increased with unusual rapidity, that the necessity for additional houses has arisen, and, to a great extent, been met, before the ruling authority of the locality was prepared with efficient means of regulating the arrangement of the new streets and the construction of the new houses. Under such circumstances it is not surprising, when the demand for building-land has considerably enhanced its value, to find that new houses are packed together as closely as possible, wherever space, however small, can by any ingenuity be found. The result of this is to be seen in the narrow streets and dark ill-ventilated passages and courts, too frequently found in numerous large towns.

In the district of St. Giles-in-the-Fields, Dr. Buchanan, when Medical Officer of Health, computed that there were upwards of seventy courts and alleys that had either no thoroughfare at all or were approached merely by covered entrances. Proper ventilation under circumstances such as these is not possible. Happily some of the worst parts of this particular district have recently, under the provisions of the Artisans' Dwellings Act, been entirely cleared, and dwellings of an improved character are in course of erection. Similar improvements, involving enormous cost, are in progress in other parts of the metropolis, and likewise in some of our large provincial towns; and it is to be hoped that the lesson taught by these expensive examples will not be lost sight of in the future by those who have yet the opportunity of regulating the arrangement of the new parts of large and increasing towns and urban districts generally.

Another result of the rapid growth of towns is the corresponding rise in value of house property, the immediate effect of which, on the labouring population, is that it promotes overcrowding, with its attendant evils. Where house-rent is heavy, the amount of accommodation available for each family will be proportionately small; hence it is a frequent occurrence for a house originally intended for but one family, though in point of actual space capable, perhaps, of fairly accom-

modating three small families, now occupied by as many as six, or even eight, distinct families, averaging six or seven persons in each. With all this overcrowding, the sanitary arrangements of the house (the only convenience, probably, being one miserable water-closet in the back yard, supplied direct from the same cistern above it which supplies water for the whole house) are merely those originally provided, under different circumstances, for the use of one family. The conditions of health, decency, and morality likely to obtain in such a house, crowded from cellars to attics with human beings of all ages and both sexes, may perhaps be imagined, but cannot easily be described.

Nor can it be said that a very much better state of things exists with regard to the dwellings of the poor in some of the more rural parts of the country. The farm labourer's cottage, consisting, as it used to do, of one or two rooms with a tile floor on the same level as the ground outside, or perhaps at a lower level, always more or less damp, and saturated with the dirt of generations, under a roof of thatch in an advanced state of decomposition, with small windows, having little or no arrangements for opening them, and accumulations of filth and refuse in the immediate vicinity of the house, often saturating the walls, is still to be met with in many parts of the country; but to the credit of many large owners of property, such are now being superseded by a better class of house, in the arrangement of which some attention has been paid to the modern essentials of health and decency.

The wretched condition of the habitations of the working class in England is of very long standing, but it was not until shortly after the institution of the Poor Law Commission that public attention was specially directed to the subject. In August, 1839, the Poor Law Commissioners were directed by the Queen to cause inquiry to be made as to the extent to which the causes of disease stated in their fourth and fifth annual reports to prevail amongst the labouring classes in the metropolis, prevailed also amongst the labouring classes in other parts of England and Wales. The results of these inquiries were subsequently communicated to the Right Hon. Sir James Graham, Bart., the Home Secretary, in July, 1842, by the eminent early Poor Law Commissioners, George Nicholls, George Cornewall Lewis, and Edmund Walker Head, in the form of a most valuable report, compiled by their secretary, Edwin Chadwick. That report, which is illustrated with several examples of the dwellings of the working classes, seems to form a sort of starting-point in sanitary reform, so far as it relates to habitations and all that concerns them. It deals, in the broadest manner, not only with the general condition of the houses themselves, but with their surroundings and neighbourhood, and the management of the whole localities of towns where the dwellings of the working classes were chiefly congregated. It shows how, "in the instance of migrant families of workpeople who are obliged to occupy inferior tenements, their habits soon become 'of a piece' with the dwelling." It gives instances showing how the noxious physical agencies of a miserable home affect the character and condition of individuals whose previous training and habits justified the expectation of better results. One example is given in detail of a young woman—a servant, highly esteemed for neatness and cleanliness—who married a serving-man. He, being retained in his situation, was obliged to take a house as near his employment as possible. His choice was limited to a few cottages—or, it may rather be said, "hovels"—of the most miserable kind, and the result was that in a few years his wife so degenerated as to become dirty,

untidy—indeed, so slatternly that her husband became dissatisfied with her and with his home; and had she and her family not been removed by her friends to a better dwelling, the disadvantages to them would have been disastrous. The report also shows how the atmosphere of the old style of cottage, being always close and polluted, is one of the agents which has tended more than almost any other to depravity, disease, and misery, engendering habits of improvidence and waste, and affecting the nervous system in a manner which tends to incite the habitual use of spirits.

The working classes, whether agricultural or manufacturing, must be housed near their employment. Apart from the indirect gain consequent upon proximity to the employer or the employer's family and property, there are immediate advantages in the avoidance of risk of disease, consequent on exposure to wet and cold, and the additional fatigue in traversing long distances between the home and the place of employment in the damp of early morning and nightfall. When the home is near the place of work, moreover, the labourer is enabled to take his dinner with his family instead of at the beer-shop.

These considerations have led, in many districts, to the crowding together of dwellings in a most objectionable manner.

In all manufacturing towns, where vast numbers of persons are employed in the development of any special trade or business, there will always be found numerous families with but small means, for whom it is essential, if due regard is had to their health and habits, that small separate houses, to hold no more than one family each, should be provided. These houses must obviously contain a certain minimum amount of accommodation. It is necessary to provide a living-room, and also separate sleeping-apartments for the parents and their children. Thus there must be at least three habitable rooms, while for those families where the children are of an age to necessitate their being separated—boys from girls—four rooms must be provided. This sort of house must also contain a small scullery, so as to allow of the living-room being kept moderately tidy, a pantry or larder, and a coal-cellar. It should likewise include a washhouse, the requisite water-closet accommodation, and a dust-bin or receptacle for ashes and dry house refuse.

In the manufacturing districts throughout the country these houses are very numerous, but the success with which they have been arranged differs very widely in the various localities. Efforts have been made in many ways by numerous philanthropic individuals and societies to provide improved house accommodation for the wage-earning classes, and such efforts have generally been attended with more or less success. Thus by degrees the more serious objections to the kind of houses for the working-classes formerly built in the busy towns of Lancashire, Yorkshire, and some other counties, have been reduced to a minimum. The houses are still clustered together in long rows, with other rows attached to the rear, as in the plans shown in Figs. 86 and 87, and thus form what have come to be known as "back-to-back" houses; but the surroundings—the yards and out-buildings—have been so regulated as to remove many of the defects which combined, in a great measure, to create the objections attributed to the class of house itself. The particular class of house referred to is, by many whose opinions are entitled to much weight, held to be a necessity in various localities, if a certain small limit of cost of construction has to be observed; and though the peculiar arrangement is one that cannot under any circumstances be recommended, it is

possible to very materially lessen, if not altogether remove, some of the worst defects in the mode hitherto commonly adopted of constructing them, and thus, where such houses are found to be a necessity, to make them fairly wholesome abodes.

As instances showing how the "back-to-back" system may be carried out with a considerable degree of success, the Saville estate at Thornhill, near Dewsbury,

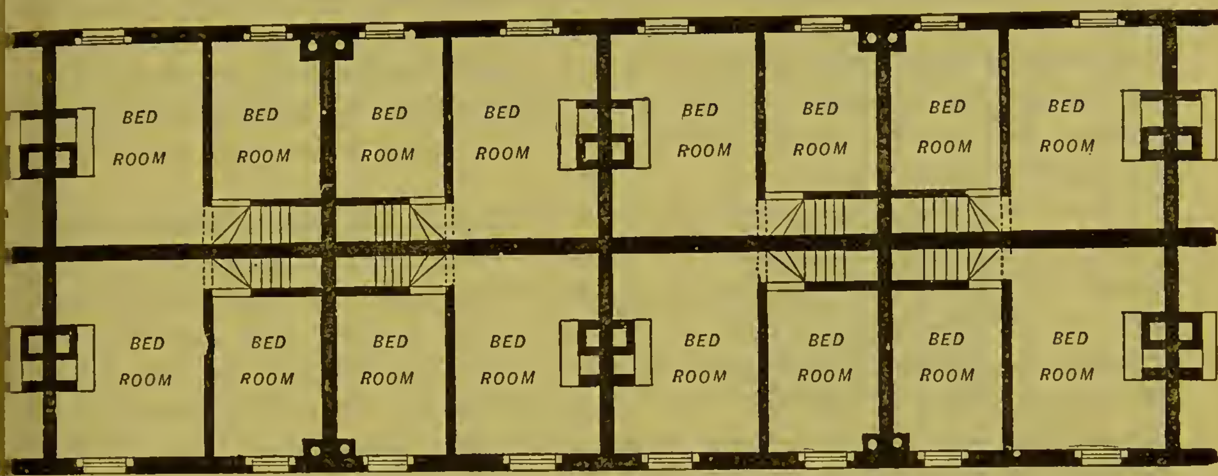


Fig. 86.—Chamber Plan (Rooms 8′ 9″ high. Attic above).

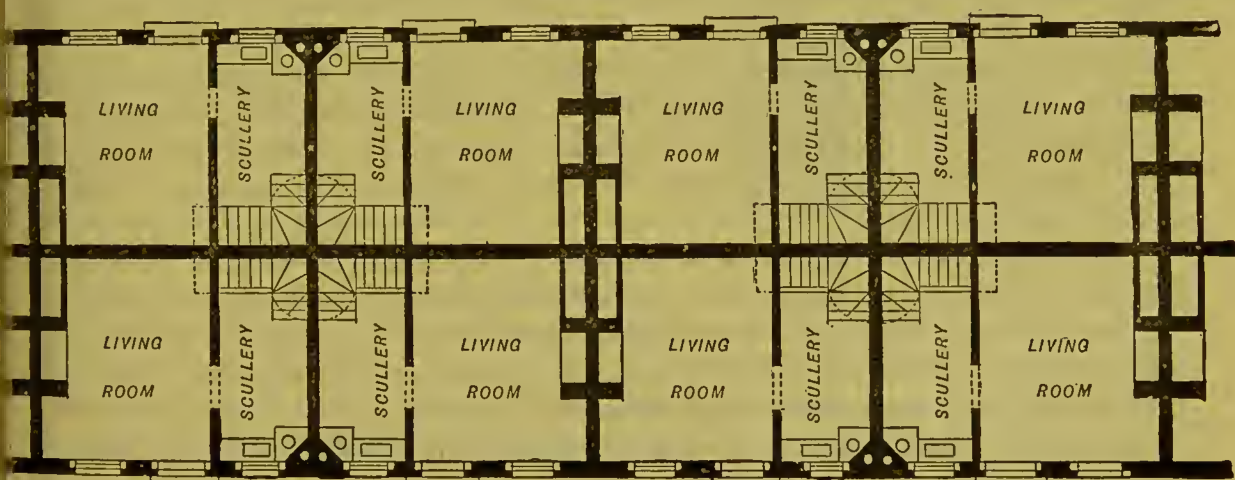


Fig. 87.—Ground Plan (Rooms 9′ 0″ high. Basement beneath)

BACK-TO-BACK HOUSES.

and Copley Village, near Halifax, may be pointed out. In both cases all houses that are built are arranged in accordance with certain specific regulations laid down by the respective owners of the estates, and intended to remove the more serious objections that are usually associated with the system. Thus, the number of back-to-back houses in one block is limited to four—two to the front and two to the rear—so that each house shall have windows or other efficient means of ventilation not only in its front wall, but also in its external side wall. Adequate space is required to be provided between the adjacent blocks of houses; and separate conveniences, ash-pits, &c., are required for each house. At Copley Village, allotment-gardens and a recreation-ground have been provided for the use of the

inhabitants, also a church and a school, the class-room of the latter serving as a village library and news-room. It will be obvious, however, that in these instances the system, being carried out on private estates and under carefully-framed regulations rigorously enforced, is applied under the most favourable conditions, not merely as regards situation and arrangement, both external and internal, but also of quality of construction. The circumstances are very different when it is applied in the low-lying parts of some large manufacturing town where, owing to the value of land, space, both within and without the houses, is curtailed to the utmost, and the buildings are allowed to be constructed by speculating builders, untrammelled by the regulations that are so essential to secure even a moderate degree of wholesomeness.

Some of the tenements in the blocks of artisans' and labourers' dwellings that have of late years been built in the metropolis, even under eminent professional supervision, possess in a marked degree the main defects of imperfect ventilation that are supposed only to exist in "back-to-back" houses. The tenements in question are arranged back to back against a central division wall, in large blocks of building, several storeys high, and having two fronts. Even in these buildings the ordinary health of the inmates is stated to be fairly good, and in that case the arrangement seems to go far to prove that if the surroundings—the privy and especially the ash-pit arrangements—and the sink and drain connections, are what they ought to be, the defects which were formerly attributed to the absence of means of through ventilation were, in reality, due to other causes. It remains to be seen, however, whether the alleged healthy condition of the inmates in these huge and comparatively new buildings will be maintained when the tenements have been constantly occupied for such a length of time that the walls, floors, ceilings, &c., shall have become saturated with the continual exhalations of their inhabitants.

Wherever possible—and in new districts and buildings it ought to be always possible—it should be regarded as a matter of primary importance for purposes of health that every house or tenement should have an adequate amount of open space not only in front of it, but also at its rear; and likewise that it should have windows in every storey overlooking such open space both in the front and rear. By this means it will be possible with very little difficulty to secure a current of air through the house at all times.

In order that this arrangement may be thoroughly efficient, it is necessary that the open space in the front and rear should be of sufficient size, and that the distance across it to the opposite building or property should be such as will allow free circulation of air about the building, and access of as much light and sunshine to such space as possible.

In front of the house the street is generally, though not invariably, of sufficient width to effect these objects; but instances are not uncommonly met with, even of recent creation, in which a house is so placed on a plot of ground as to have a totally inadequate amount of space in front of it. This happens sometimes when, as in Fig. 88, a house, or a row of houses, is built in the back garden of another house, a passage-way being afforded thereto by the side of the front house. Such instances ought always to be prevented, and the local building regulations should be so framed as to render such an arrangement inadmissible.

The requisite amount of space at the rear of a house should extend across the entire width of the house, and ought to be not less in any case than one hundred and fifty to two hundred square feet in extent; and the distance across this space, from the rear wall of the house to the opposite property, should increase in proportion to the height of the house, the minimum distance being, in the case of a house of small height, from ten to fifteen feet where land is valuable, but more where a larger extent can be obtained.

The ordinary labourer's cottage of the country, for the sake of economy, is usually built either in a row of several cottages, or in semi-detached pairs, and two storeys in height. The ground-floor rooms should not be less than nine feet, and the upper rooms eight feet high. The living-room, being the principal room in the cottage, and the one used in common by all the inmates, should be as large as circumstances will admit, and, if possible, of not less than one hundred and fifty square feet. It should have a space of twelve feet by ten feet clear of the chimney-breast and other projections. At least one large cupboard, lighted if practicable by a separate window to open on pivots, should be provided at the side of the chimney-breast. Attached to the living-room should be the scullery, containing a copper with furnace, also sink, plate-rack, &c. This room should have a superficial area of about seventy-five feet—a proportion of about 10 feet by 7 feet 6 inches forms a convenient shape for a cottage scullery. The pantry and fuel-store may be entered from the scullery, either on the same level or by a flight of stairs to a well-ventilated cellar, or the fuel may be stored in a shed in the back yard. In this yard also will be the privy accommodation and the dust-bin. The staircase should, where practicable, start from an enclosed porch, giving access to the living-room. The porch is useful to the latter as a protection from the weather, and it serves for the deposit of tools, wet outer clothing, boots, &c., which otherwise would have to be taken into the living-room. The stairs ascending from the porch, moreover, are not so likely to serve as a shaft conveying heat and vitiated air from the living-room to the bed-rooms.

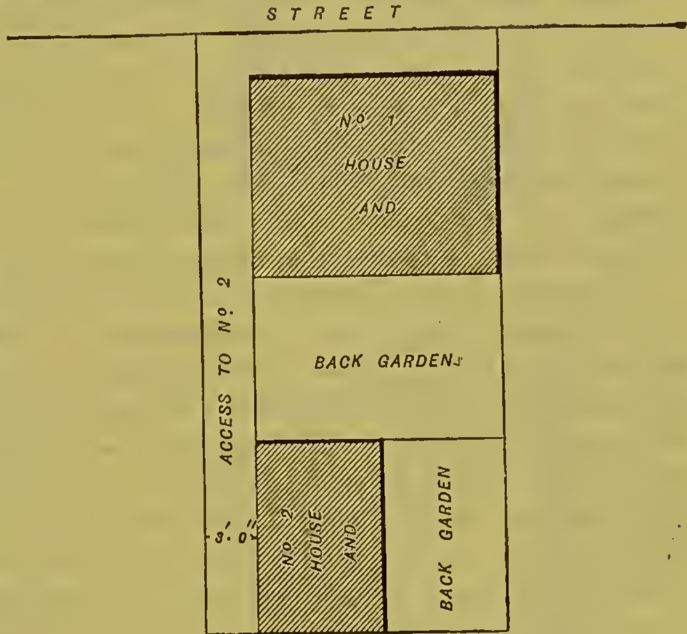


Fig. 88.

The bed-rooms should be as large as the circumstances permit—the one for the parents should have a floor-area of from 100 square feet to 120 square feet, and ought to have a fireplace and good cupboard. In dimensions 12 feet by 10 feet would be a convenient size. The two bed-rooms for the children should be not less than 50 feet superficial each; one of them could probably be about 80 feet superficial, which would answer sufficiently well for two children. If a fireplace can be arranged

in these rooms so much the better. It is desirable to separate them as completely as possible, because sometimes one of them may be used by a lodger, and in that case the separation is more necessary than where the inmates are all of one family. A pair of cottages, such as has just been described, would cost probably fully £300, but if, as is sometimes the case, though obviously very undesirable, the size of some of the rooms be slightly curtailed, and the space occupied by the staircase be taken off the living-room, some reduction from that sum would be effected.

The plans on page 169, as issued by the Enclosure Commissioners,* show a very convenient arrangement of a pair of two-storey semi-detached cottages, arranged somewhat on the plan just described. The rooms are of fairly good height and suitable dimensions. In one of the cottages a bread-oven is provided in the scullery in addition to the boiling-copper provided in each. In many parts of the country a bread-oven would be indispensable in every cottage. In the other cottage it will be observed that, by way of compensation, the chimney opening in the living-room is shown to be of greater width than the one in the cottage with the oven. This would allow of a more convenient kitchen-range being provided, one containing an iron oven for baking meat, bread, &c.

A cheaper kind of cottage is shown in Figs. 95 to 100, page 171,† the plans being numbered as by the Commissioners. In these the accommodation is all on the ground floor. These cottages, which are recommended by the Enclosure Commissioners (and are designed principally for Scotland) comprise in Fig. 95 a living-room, 16 feet by 12 feet, and two bed-rooms, 13 feet by 9 feet, and 10 feet by 6 feet 9 inches respectively; also a scullery, good entrance-lobby with cupboard and a pantry. This cottage, as will be seen from the plan, is intended for a married couple, their two or three young children occupying one bed-room, while the living-room, being of large size, would admit of a bed being placed in it when the children, being of different sexes, would need separate bed-rooms. Of course the requisite privy accommodation, with coal and wood store, &c., would be arranged out of doors, but the plan is probably the least costly that is possible for the amount of accommodation provided. In Figs. 97, 98, and 100 there are three distinct bed-rooms in addition to the living-room, and it will be observed that in all these plans the rooms are to have a minimum height of 10 feet, and that the arrangement provides ample means of thorough ventilation in each cottage.

The ordinary artisan's house in the manufacturing town comprises very much the same accommodation as that of the labourer's cottage in the country, but in consequence of the increased value of the land on which it is built, the necessary rooms and offices have to be packed closer together than is desirable in any case, or than would be necessary where the land is of mere agricultural value. Thus in towns, the houses are necessarily arranged in rows with only the minimum amount of open space in the front and rear that is requisite for convenience of traffic and circulation of air. In many towns where rows of houses are built attached to each other back-to-back, the necessary out-offices—privy accommodation and ash-pits — are placed at intervals between blocks, often comprising as many as sixteen or twenty houses—eight or ten facing one street, and the same number

* Sheet 5 of Enclosure Commissioners' Designs.
† Sheet 2 of Enclosure Commissioners' Designs.

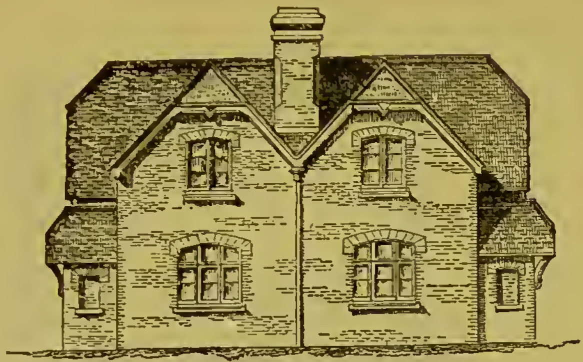


Fig. 89.—Front Elevation.

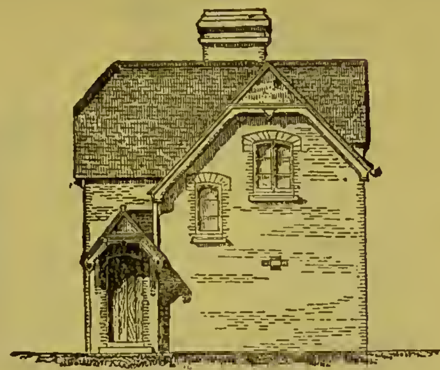


Fig. 90.– End Elevation.

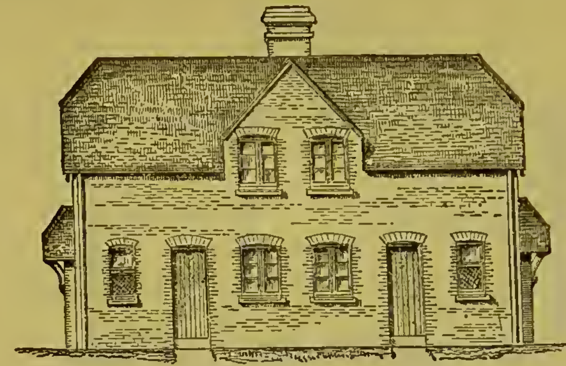


Fig. 91.—Back Elevation.

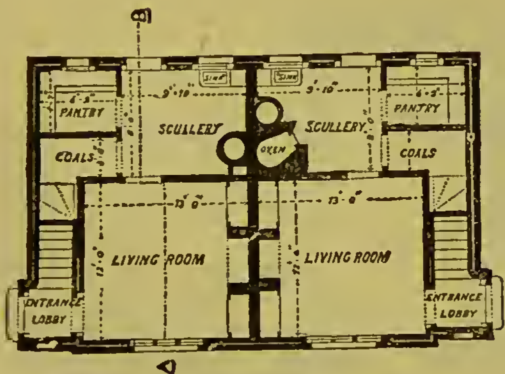


Fig. 92.—Ground Plan.

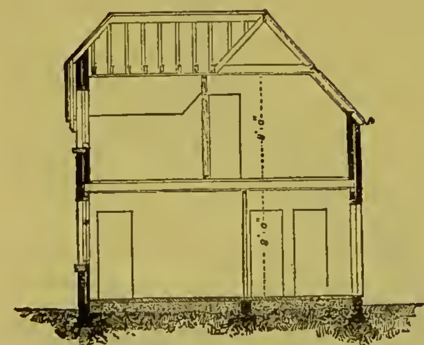
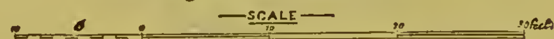


Fig. 93.—Section at A B.



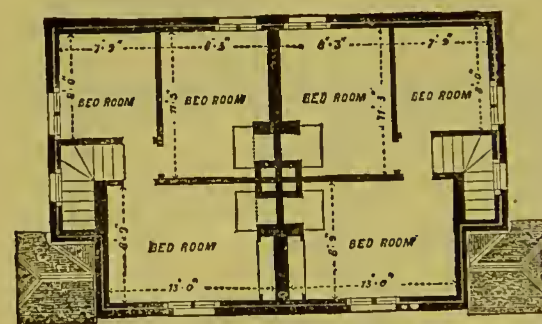


Fig. 94.—Chamber Plan.

LABOURERS' COTTAGES

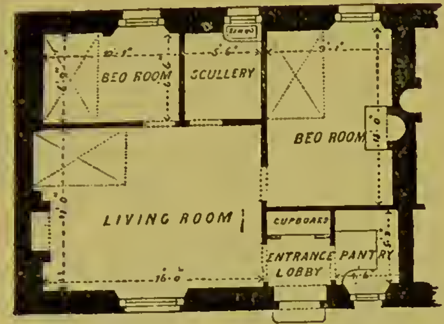


Fig. 95.—Ground Plan No. 6.

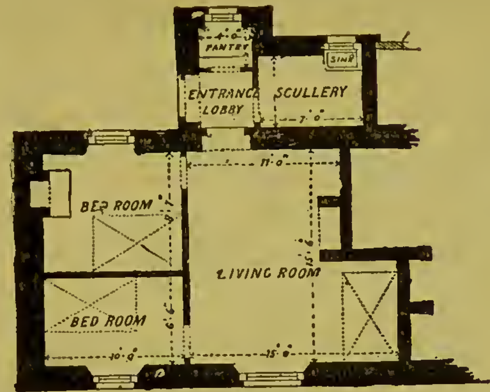


Fig. 96.—Ground Plan No. 7.

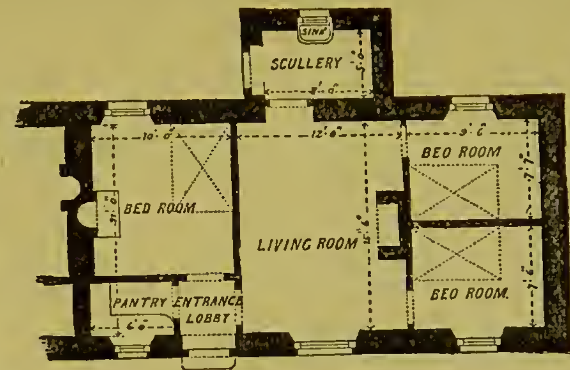


Fig. 97.—Ground Plan No. 8.

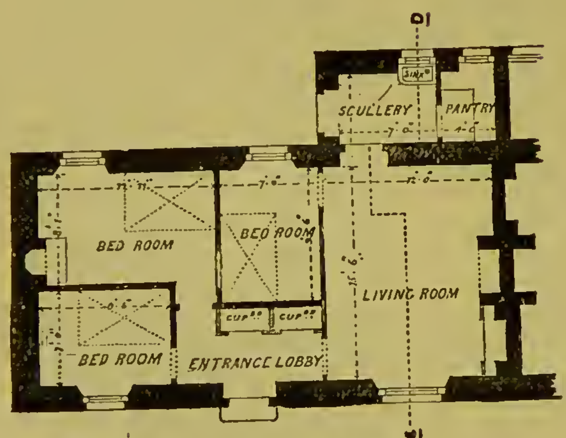


Fig. 98.—Ground Plan No. 9.

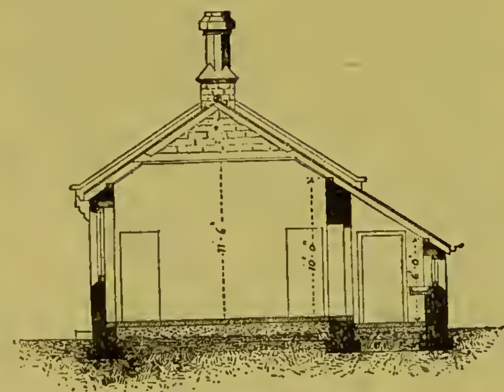


Fig. 99.—Section C D No. 9.

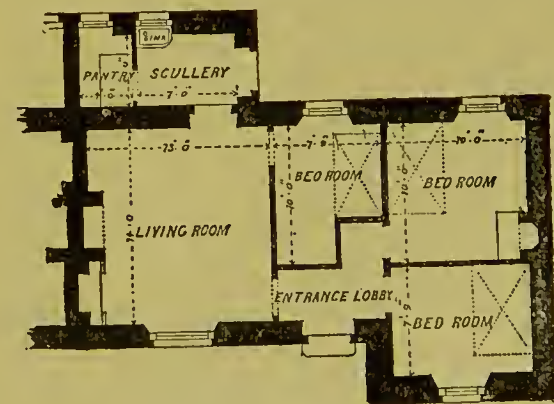


Fig. 100. Ground Plan No. 10.

LABOURERS' COTTAGES.

at the rear facing another street. Thus the occupiers are subjected to the serious inconvenience of having to go a considerable distance in order to relieve the wants of nature—an arrangement objectionable on every ground, and opposed to common decency. This plan is unfortunately not confined to back-to-back houses alone. In some of the principal towns, houses having open space at the rear as well as in front are still to be found with detached privy accommodation common to several houses; but it is to be hoped that this arrangement is being prevented in new buildings, and remedied, as far as circumstances permit, in the case of old buildings.

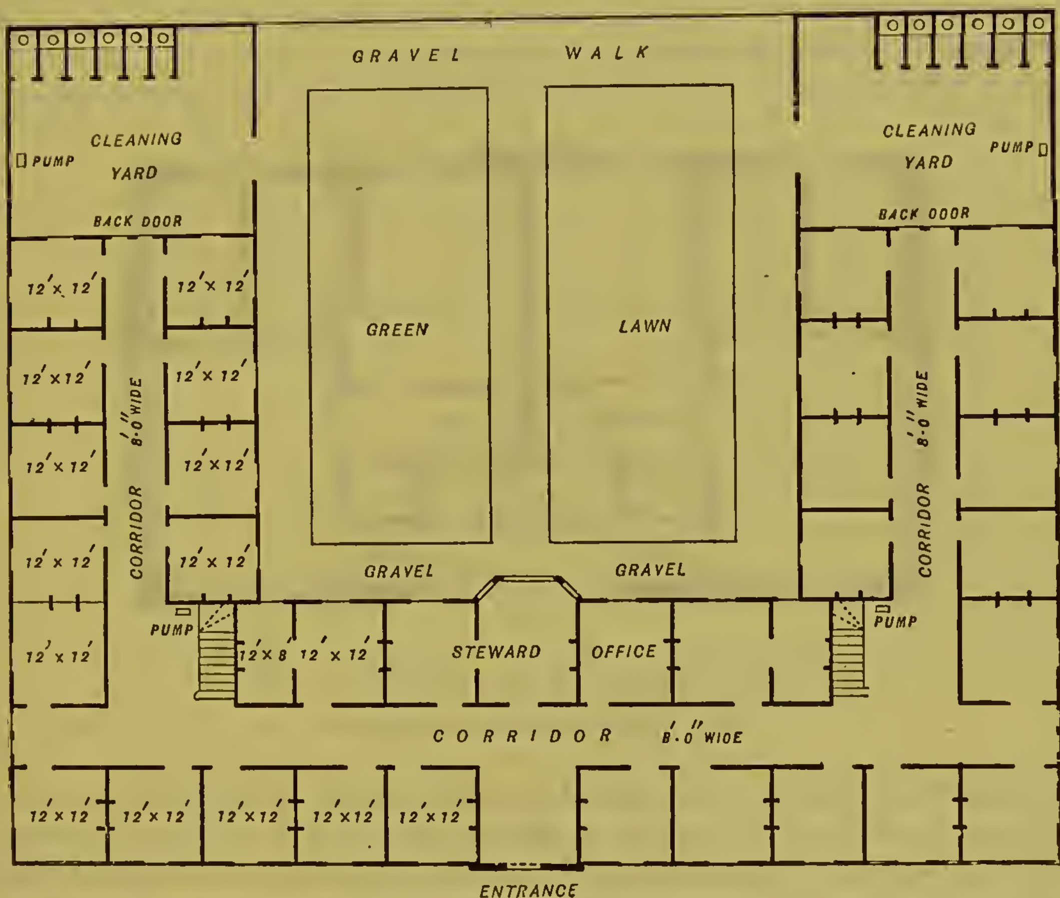


Fig. 101.—Plan of Lodging-house.

In the Report of Mr. Chadwick, above referred to, is a plan by the late Mr. Sydney Smirke, architect, of a "Public Lodging-house," which is probably the first suggestion for providing a block of apartments for the labouring classes. It consisted of a three-storey building arranged as shown in the annexed illustration (Fig. 101), and provided fifty or sixty separate rooms. This step was followed shortly afterwards by the formation, in 1844, of the Society for improving the condition of the labouring classes, whose object was to provide those classes, either by alteration or adaptation, with suitable dwellings; and from that time that Society and others moving in the same direction, assisted by the legislature, have provided blocks of artisans' and labourers' dwellings in the metropolis and other towns of the kingdom.

In 1851 the above-mentioned Society, of which the late Prince Consort was

President, exhibited at the Great Exhibition in Hyde Park a block of model houses for four distinct families. This block, which was designed by Mr. Henry Roberts, F.S.A., the honorary architect of the Society, may still be seen at Kennington, where it was subsequently erected. Each of the four residences contains a living-room 14 feet 2 inches by 10 feet 4 inches, a parents' bed-room, 11 feet 5 inches by 9 feet, two smaller bed-rooms, for children, each 9 feet by 5 feet 2 inches, a small scullery, a water-closet, and a porch. Except that the children's bed-rooms are of very limited size, the plan (Fig. 102) is generally satisfactory. The construction is nearly entirely of hollow bricks, and there is a complete absence of timber in the floors and roofs, which are formed of hollow brick arches, thus going far to make the building safe against fire.

A practical example of what may be done by a large employer of labour, in

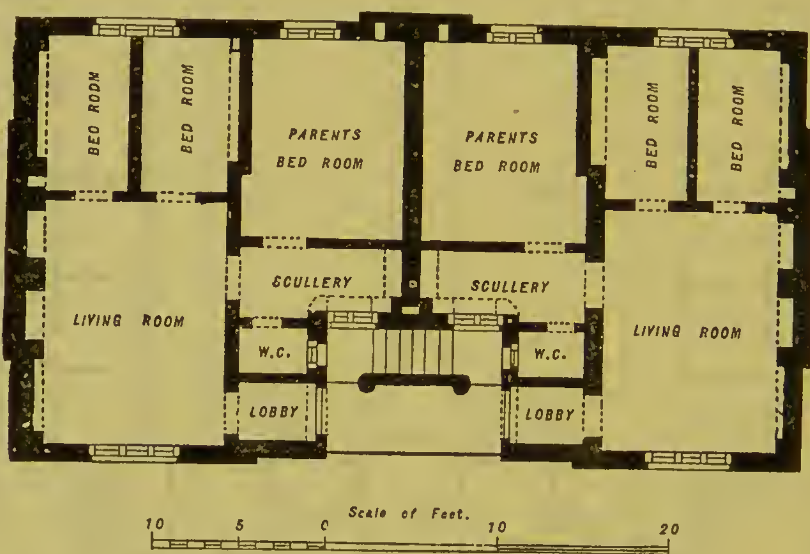


Fig. 102.—Block of Artisans' Residences.

the way of improving the condition of his workpeople, is to be found in the town of Saltaire, near Bradford, erected by the late Sir Titus Salt. Here, dwellings for several hundreds of workpeople have been built, and supplied with suitable drainage, water, and gas. For the use of the inhabitants, a church, schools, lecture-room, library, baths, and washhouses, and a large dining-room, with kitchen attached, have been erected. A noteworthy feature in the scheme is that no public-house or beer-shop is to be found on the estate. Some of the effects of providing these numerous workpeople with well-arranged and wholesome dwellings are to be seen in the important facts—that the rate of infant mortality is very low as compared with that of the neighbouring town of Bradford, and that illegitimate children are rare.

Much advantage results from numerous well-managed building societies. Akroydon, a village erected by Mr. Edward Akroyd, in conjunction with the Halifax Permanent Benefit Building Society, is the outcome of a scheme for enabling workmen to become possessed of healthy and well-built houses. By an arrangement with the building society, under which Mr. Akroyd undertook to provide the plans and supervision, and to defray all the expenses connected there-

with, and likewise to guarantee the fulfilment of the contract within the estimate, workmen were not only able to purchase their houses on exceptionally easy terms, but had the additional guarantee that they were acquiring unusually well-built houses.

A somewhat similar scheme to the foregoing was started by the late Sir John Crossley, at West Hill Park, Halifax, where, by the co-operation of landowner and building society, the workman finds it possible to become the possessor of a soundly-built and wholesome house at practically no more than cost price.

In some of the large provincial towns as well as in the metropolis, efforts have been made to provide proper dwellings for the poor as a strictly commercial undertaking, and these efforts, under judicious management, have been attended, in many instances, with some considerable success. In London, the Industrial Dwellings Company, of which Sir Sydney Waterlow, Bart., is chairman, has erected a number of blocks of dwellings, some of the blocks containing twenty, some sixty or a hundred, and some as many as three hundred and five hundred distinct dwellings, each dwelling holding, on an average, four or five persons.*

By the munificence of the late Mr. Peabody, who gave and bequeathed altogether half a million sterling for the purpose, the poor of London have had a great benefit conferred upon them in the last fifteen years by the erection of several blocks of improved dwellings. In the sixteenth annual report of the trustees of this fund, for the year 1880, it is stated that as many as 2,355 separate dwellings have been provided. These dwellings comprised 5,170 separate rooms, exclusive of bath-rooms, laundries, and wash-houses, and were occupied by 9,899 individuals. Additional dwellings were then in course of being provided, which, it was anticipated, would supply further accommodation for 760 families, or upwards of 3,500 individuals. The dwellings already occupied were tenanted by families, the head of each of which earned on the average £1 3s. 4½d. per week, and the average weekly rent of each dwelling was 4s. 4½d., and of each room 1s. 11½d., the rent in all cases including the free use of water, the laundries, sculleries, and bath-rooms, by the tenants. The rate of mortality in these buildings is stated to have been 19·71 per thousand, which is 2·49 in the thousand below the average of the metropolis for the same period. The net gain for the year from rents and interest (including £1,500 for the sale of a plot of land) was about £26,779, which exhibits a fairly satisfactory result.

There has been much improvement in the arrangement of dwellings in blocks since the earlier dwellings were erected. In Mr. Smirke's plan of 1841 (see Fig. 101, the rooms were arranged along both sides of one general corridor on each floor. More recently, in some of the earlier erections by the Peabody trustees, a main corridor likewise forms the means of access to the several dwellings on each floor. Even where this corridor is of good width, however, with windows at the extremities and openings in the staircases, this is but an unsatisfactory arrangement. The corridor prevents the families from having that amount of privacy and independence which is always looked for in the residence of every class of Englishman. The corridor, moreover, is always difficult to ventilate; and unless it can be well lighted, which is almost impossible in a large building, and in constant communication with the external air, it is a source of danger

* Report on Poor-Law Relief in St. Pancras, by Thos. E. Gibb, Vestry Clerk, 1879.

rather than otherwise to the residents in the building, since it receives the vitiated air from many dwellings, and as some of them cannot fail to draw a portion of their supply of air from the corridor, there is always disadvantage, and occasionally danger, arising from this particular arrangement. The corridor plan, having rooms along both sides of a corridor, is now very generally condemned in all large buildings intended for occupation, whether they be barracks, workhouses, schools, or otherwise, as it is impossible under such an arrangement to ensure effectual ventilation.

Another defect in the earlier plans for blocks of dwellings was that the several blocks were directly attached to each other at right angles, so as sometimes to form four sides of a quadrangle. Such an arrangement is always objectionable, inasmuch as it is impossible to secure a free movement of air in the courtyard. This arrangement cannot fail to produce a certain amount of stagnation in the atmosphere, and as some parts of the quadrangle are precluded from ever receiving any direct sunshine, there is a most objectionable degree of dampness and unwholesomeness in the air, which the ordinary arched openings, ground storey high only, are quite insufficient to remedy. In every case where several blocks of building surround an open space, it is essential that they should be completely separated from each other at the ends by openings 20 feet or 30 feet wide, so as to allow free circulation of air.

The most satisfactory arrangement of apartments appears to be that by which each distinct set of rooms is entered directly from the external air. This is effected either by providing a separate main staircase open to the outer air for every two vertical sets of apartments, or, where one staircase has to serve for more than two tenements on each floor, to form a balcony or verandah gallery along the outside to afford access to the several tenements.

In the class of building under consideration, it is necessary to supplement the accommodation ordinarily required in an artisan's cottage by some few conveniences to meet certain difficulties that would otherwise be experienced in consequence of the absence of a separate yard in connection with each tenement. Thus, a private coal-store has to be arranged conveniently accessible from each tenement, and possibly a lift for raising coals to the several floors. Shoots also have to be provided for getting rid of dust and refuse, and these have to be arranged so as to preclude the possibility of their acting as shafts conveying unwholesome air from the dust-receptacle at the bottom into the apartments on the upper floors. Suitable slop-sinks are likewise necessary in the upper storeys, and these have also to be placed in such a position as to render them free from objection.

Another feature that has been successfully introduced into these tenement buildings is the flat roof, which serves, when provided with a suitable parapet, as an excellent place of recreation for children. It is also frequently used as a drying-ground for wet linen, and in many instances suitable washhouses have been constructed on the roofs of these buildings, for the use of the several occupiers of the tenements beneath.

It has been stated above that some of the blocks of industrial dwellings comprise several hundred tenements. It must be borne in mind, however, that in the metropolis, at any rate, there are certain restrictions to which the tenements in

buildings of large size are subject. Thus the Building Act requires that separate sets of chambers or rooms tenanted by different persons shall, if contained in a building exceeding 3,600 square feet in area—*i.e.*, 60 feet by 60 feet—be deemed to be separate buildings, and be divided accordingly, so far as they adjoin vertically, by party walls, and, so far as they adjoin horizontally, by party arches or fireproof floors. This regulation, which is primarily intended as a precaution against fire, is of some advantage in a sanitary point of view, inasmuch as it tends to insure the complete isolation of the several families occupying the block one from another.

An element of vital importance in the consideration of any kind of improved dwellings for the wage-earning classes, whether it be the country labourer's cottage or the blocks of dwellings for the mechanic of the town, is the choice of materials and the mode of construction to be employed. In country places the choice of materials will be to a great extent limited by local products and considerations of carriage, labour, etc. Local prejudices, too, must be taken into account, and old customs ought, so far as they are compatible with true sanitary laws, to be freely adopted. Probably one of the most injurious customs of ordinary cottage and farm-house building is that of paving the ground-floor rooms with bricks, often of a very porous nature, and laid on the earth without any intervening bed of concrete. For many reasons it is frequently undesirable to floor the lowest storey of a labourer's cottage with wood. While, therefore, it may be necessary to retain the old method of flooring with bricks or tiles, it is of the utmost importance that, whichever of these materials be used, it should be laid on a solid and impervious bed of concrete. In very damp soils the concrete should be covered with a layer of asphalte or tar.

Another time-honoured custom pertaining to the labourer's cottage is that of roofing with thatch. Picturesque and warm as thatch undoubtedly is, it nevertheless has disadvantages which quite outweigh these qualities. Being entirely vegetable in its nature, it is, of course, subject to comparatively rapid decomposition, which is encouraged by alternations of drenching rain and scorching sun. It is, moreover, of a most inflammable nature, and affords unlimited harbour for insects. From all considerations, therefore, of healthy dwellings for the rural labouring population, thatch should be dismissed as extremely undesirable.

In most country places the casement is the all but invariable type of window, and its size is usually small in proportion to the size of the room. While the size can be increased with advantage, it will frequently be found advisable to retain the casement form: firstly, because it is a form to which many people are greatly attached, and therefore there is more chance of its being properly used than any form would have to which they were unaccustomed; and secondly, because, in many places, there would be a difficulty, or, at all events, increased cost, in repairing sliding sashes; and this circumstance would, in many instances, result in the disuse of the window for purposes of ventilation.

What has been said about windows applies equally to doors, stoves, and, in fact, to all the necessary fittings and appurtenances of a labourer's cottage. They should be as simple and strong in construction as possible, and, as far as practicable, should take the form of those habitually in use in the locality. Above all things, it is necessary that repairs, when required, should be within the capacity of local skill to effect.

While greater latitude in the choice of materials is available for the artisans'

dwellings in large towns, it is of equal necessity to select only such materials as will stand the test of the wear and tear necessarily involved. In any system of combined dwellings it will also be necessary to build in the manner best fitted to guard against fire. While the elements of strength and durability are necessarily provided in any fire-proof construction worthy of the name, it will also be found that the nature of the materials used is such as to comply with proper conditions of health. Into any such system concrete must largely enter. As a material for floors it is, probably, unrivalled, while the improvements which are being continually made in the manufacture of Portland cement, and the attention and skill which is being devoted to the application of concrete to various purposes, point to almost unlimited possibilities in the use of this valuable material. We must look to the increasing methods of application of concrete, both to constructive and decorative purposes, for the means of substituting a hard and impervious material for the soft and perishable wood used for skirtings and other purposes.

Fittings of every description must, of course, be of as strong and durable a nature, and of as simple a construction as possible. Any delicate mechanism, or anything which can easily be put out of order, is inadmissible. Pipes for conveying water should be of iron, in preference to lead. All such fittings as taps and valves should be of the simplest kind, and as strongly made as possible. Contrivances for regulating the supply of water should be fixed in positions accessible only to the proper authorities in charge of the repairs of the building.

CHAPTER XVII.

COMPOSITE MIDDLE-CLASS HOUSES.

Evils of Ordinary Lodging-houses—Advantages of Houses in Flats—Example of the Plan in an "Island" of Regent Street—Advantages and Disadvantages of the Plan.

In the progress of improvement in the arrangement and construction of dwellings in large towns, the wants of the middle classes seem to have been almost wholly lost sight of. Whilst on the one hand numerous houses or suites of chambers arranged in flats supply the wants of the more wealthy, on the other hand, the necessity for the provision of proper dwellings for the wage-earning classes has brought into existence various companies and associations for accomplishing that desirable object, and has also been the subject of a special Act of Parliament. The artisan can take his choice between the numerous blocks of model dwellings erected specially to accommodate him, or, if he desire a purer air than London affords, he has only to travel a few miles out of town, and he will find, as at Shaftesbury Park, Battersea, or Queen's Park, Kilburn, whole towns of cottages, also specially erected for his convenience. Nor will he find that the bare necessities of his domestic life have alone been provided for. Coffee palaces, clubs, schools, baths and washhouses, and even temperance music-halls are provided, either by a paternal government or by the contributions of individuals. With all this patronage, not unfrequently overdone, of the working man, but little or nothing has been done in a like direction for the class of people who, while earning wages frequently less in amount than those of a first-class mechanic, have nevertheless constantly to preserve an outward appearance of gentility which is not essential to the latter. The city clerk, or the assistant in a shop, has no choice but to make the best of a room or rooms, bearing in height from the ground an inverse proportion to the amount of his income, and situated probably in or about Bloomsbury, Clerkenwell, or else in some more distant suburb. Here he will have to retire after the labours of the day, often onerous enough, and with his own hands prepare what food he may require, or obtain it at the nearest eating-house. Take an ordinary lodging-house in such a locality as Bloomsbury, for instance. The house itself is, including basement, five storeys in height. Originally intended for one family, it is now inhabited by three or four. The basement, dark, damp, and stuffy, is occupied by the proprietor and his family. In rooms seldom or never visited by the genial rays of sunlight, reeking oft-times with the foul exhalations of defective drains or of decaying refuse under the floor-boards, the accumulations of years, a family of five or six adults pass the greater part of their existence. The ground floor contains the "parlours," front and back, with perhaps a third room behind all. The first floor is the best and most expensive, the "drawing-rooms" being in point of size and position the most eligible in the house. The two remaining floors will generally be found to be further subdivided, and

lessening in value, until the attics, the most exalted in height but the lowest in point of rent, are reached.

In such a house as this there may be, and frequently are, one or two families in addition to that of the lodging-house keeper. The discomfort, the want of privacy, the absence of adequate sanitary appliances, and the consequent loss of decency and lowering of the moral tone, involved by such a state of affairs, are at once obvious defects.

Nor is it by any means a rule that each tenant is lodged entirely on one floor. The first-floor lodger may very possibly have one room on the top floor, and the ground-floor lodger the back room on the second floor, and thus the whole system is so mixed and the tenancies so dovetailed into one another that privacy is reduced to a minimum.

When, further, it is remembered that the safety of all the inmates is, to a certain degree, in the hands of each, the consequences of a fire breaking out at night would be terrible.

What then is the remedy for all this? Surely the adoption, in the case of families, of a system of dwellings in flats of a class intermediate between Victoria Street and Peabody Square, and for the unmarried men, associated homes or chambers on an improved system. Nor should it be forgotten that some provision must be made for the increasing class of young women who have to seek their own livelihood either in shops, offices, or warehouses. Something has been done in this direction by the Girls' Friendly Society, who, in 1879, opened a house in the neighbourhood of Holborn for the accommodation of young women engaged in business. The house is an old one, and not specially suited to the purpose; the best, therefore, had to be made of existing circumstances. Three rooms on the first and second floors were divided by wood and glass partitions into cubicles; the rooms on the top floor not being sufficiently high to allow of such an arrangement with due regard to ventilation, were simply fitted up as bed-rooms for two or more in common. The ground floor serves as common parlour, with a room for study or writing behind. A large and unusually light room in the basement (the window having been specially formed for drawing purposes) forms a cheerful and convenient dining-room. The management of the house is in the hands of a lady superintendent, and the idea which is prominent in the whole system is that of a home. That there is a very large and real demand for accommodation of this kind is proved by the ever-increasing applications for rooms, and the genuine appreciation by the inmates of the comforts afforded.

Something on these lines seems to be needed to meet the requirements of the very large number of single men of varying ages who are employed in the large mercantile and commercial houses in the City. What seems to be required is a number of chambers, some of which may be arranged in pairs, some singly, of sizes and rents proportioned to varying incomes, with a large common room available for all inmates. On the ground floor of the house there might be a restaurant, but this should be entirely independent of the chambers above. It should not, in fact, be a matter of necessity for the inmates of the chambers to use the restaurant at all. Perfect freedom on this point being granted, it would probably be found that in practice the great majority of the inmates would make use of the restaurant if it were efficiently managed. On the other hand, an inefficient restaurant which

the tenants above were compelled to frequent would greatly prejudice the usefulness of the chambers; while it is doubtful whether the occupiers of the chambers above would be alone able to give the restaurant sufficient support to maintain it. Without expressing any opinion on the vexed question of total abstinence, it may be suggested that the upper part of a large coffee tavern offers exceptional advantages for the arrangement of bachelors' chambers. The class of the tavern would probably have to be somewhat different from the majority of those at present opened in London, but this could probably be managed by increased prices and improved accommodation.

The question of how best to provide for the other occupants of the typical lodging-house—the married lodgers—leads naturally to a somewhat more comprehensive subject. The manner in which the middle classes in London and most of our great towns are housed may, without exaggeration, be said to be bad in principle and inconvenient in practice. Excluding suburban houses and detached villas, the kind of house to be found in such a street as Gower Street may be taken as a typical example. The value of land, a necessary element in all calculations relating to house-building, has a natural and obvious tendency to increase with increased proximity to great commercial centres. It is this fact which has operated to cause builders to erect upon the narrowest strips of land houses whose vertical height compensates for their confined area at the ground-line. This piling up of storey upon storey between two party walls, each storey containing but two rooms, has become a tradition of which it will take years to demonstrate the folly.

Supposing now the ground upon which, say, six of these houses are built is vacant and available for building purposes. How much more conveniently this space could be utilised by arranging each house horizontally instead of vertically? And not only so, but several houses of various sizes could be arranged where formerly there were six, each one a copy or nearly so of all the others. Even in the matter of the ground at the back, now usually the undisputed domain of cats, the improvement effected by the demolition of the five party fence walls would, by throwing all the gardens into one of fair size, make it available as a common recreation-ground.

The wisdom of adopting this system of arranging dwellings in flats is even more obvious in the case of shops. In a paper which Mr. William H. White, Fellow and now Secretary of the Royal Institute of British Architects, read before that Society, on November 19th, 1877, and from which the accompanying plans are, by permission of the Council of the Institute, reproduced, an island of shops in Regent Street is taken as an example of the existing state of things, and it is shown how the same space of ground may be more advantageously covered by adopting the system, prevalent in Paris and the chief cities of the Continent of Europe, of dwellings in flats.

Describing the island (Fig. 103) as it at present exists, Mr. White says:—"Bounded on the principal side by Regent Street, it has Warwick Street on the east, Beak Street on the north, and Regent Place on the south. . . . Originally there were twenty-eight shops and houses upon it: there are now only twenty; and this apparent radical change has been effected without much visible alteration in the exteriors. The two houses in the centre fronting Regent Street have

been amalgamated. In course of time those two houses have absorbed another house at the back of them, and possessing a frontage in Warwick Street; then two more houses south of the latter, in the same street, have also been absorbed. Thus five houses have become one house. At the corner of Beak Street and Regent Street three houses have become one. Again, No. 138, Regent Street, has run through to No. 32, Warwick Street, and the two houses are now one. In Regent Place, two houses, forming together about thirty feet frontage, have become one house, yet the character of the construction has not changed. The main divisions between the twenty-eight houses still exist; only holes, large and

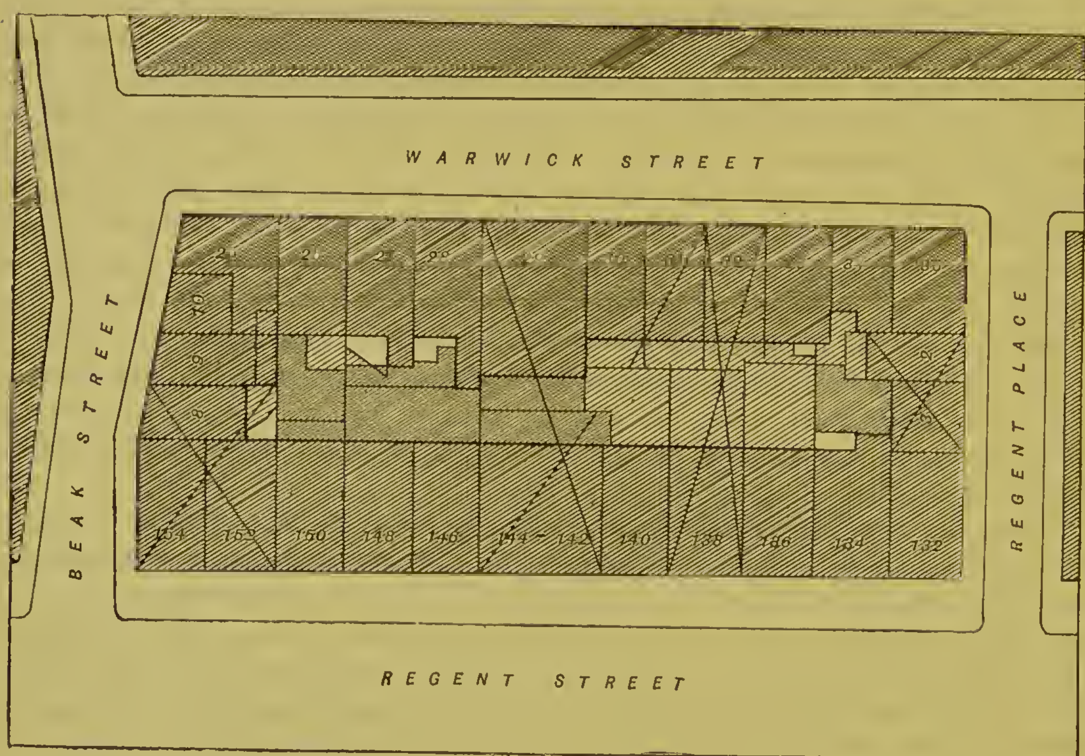


Fig. 103.—" The Island." (Original State).

small, have been made in the party walls. This desire, or rather necessity, for natural extension—for extension, that is to say, of space at the same level—is experienced all over central London, and one process of filling up the internal breathing area of an island of buildings very much resembles another. In this instance, twenty-eight houses were built close together, so that the principal front of each formed the continuous elevation of four streets. The twenty-eight houses each possessed a back yard or garden, and though it was only possible for draughts of fresh air to enter the internal area at intervals, still, after a fashion, it was breathing-space. Bit by bit this breathing-space has been filled up; half a dozen well-holes remain to convey light and air to the lower storeys; and, including the basement, each of the twenty-eight (now twenty) houses is five storeys high, the top storey in most cases being contained in the roof. I propose to show how this island, unhealthy and uncomfortable, might, under the Parisian system of plan, be healthy and comfortable; how a few of the shops might have the means of extension at the same level larger than the largest shop now on the island;

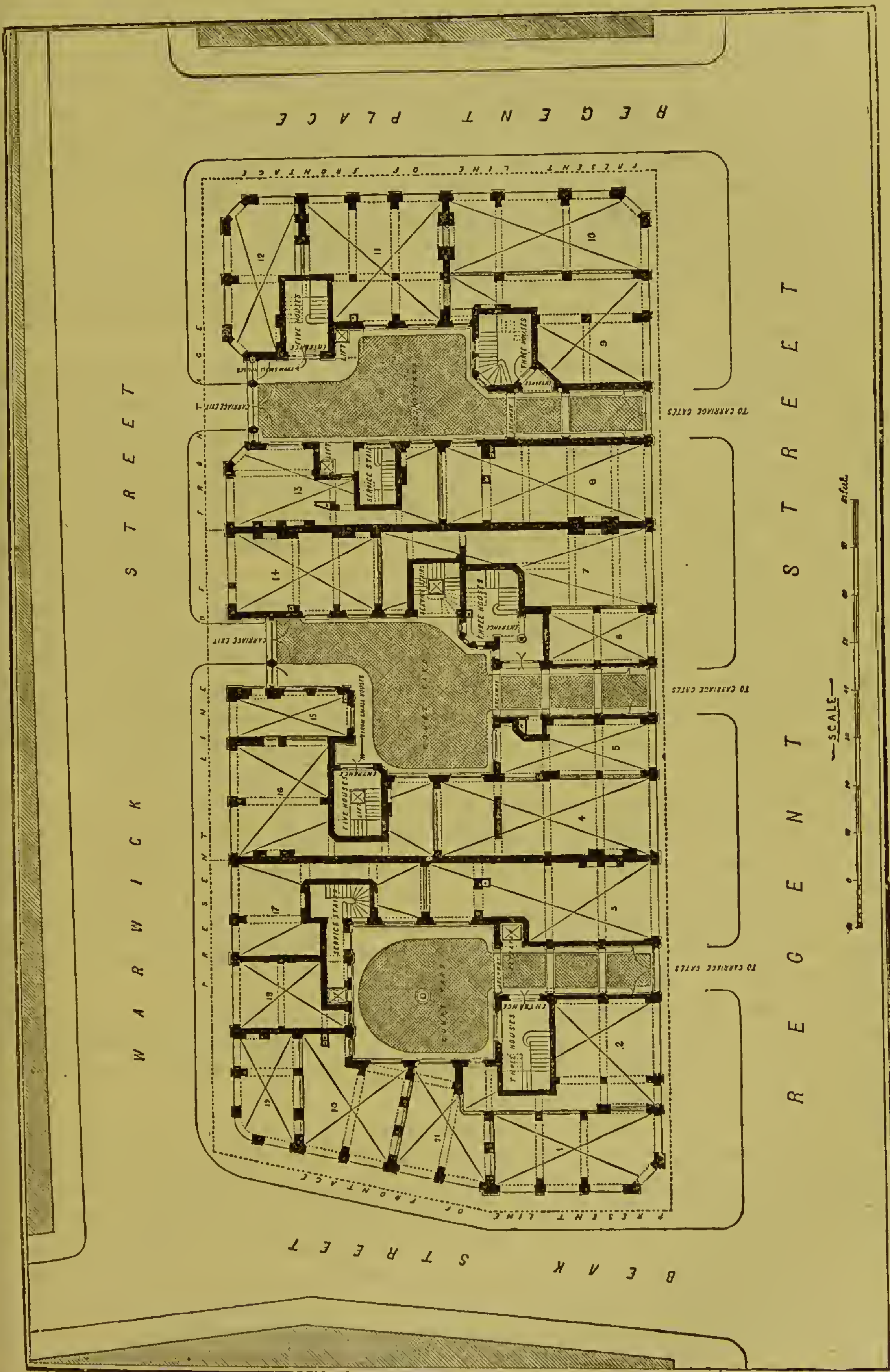


Fig. 104.—"The Island." Improved Ground-plan—Shops.

how all the shops might be distinct from the residences erected over them; how, instead of sham party walls pierced and mutilated, there need be only two solid vertical divisions; how, from the necessary connection of the internal courtyards with the external streets, the gradual filling up of those courtyards with even low buildings would be impossible; how, in fine, forty shops and houses of different sizes might be made to occupy less space of ground than the twenty shops and houses of different sizes which now crowd the island, and without increasing the average height of the front walls."

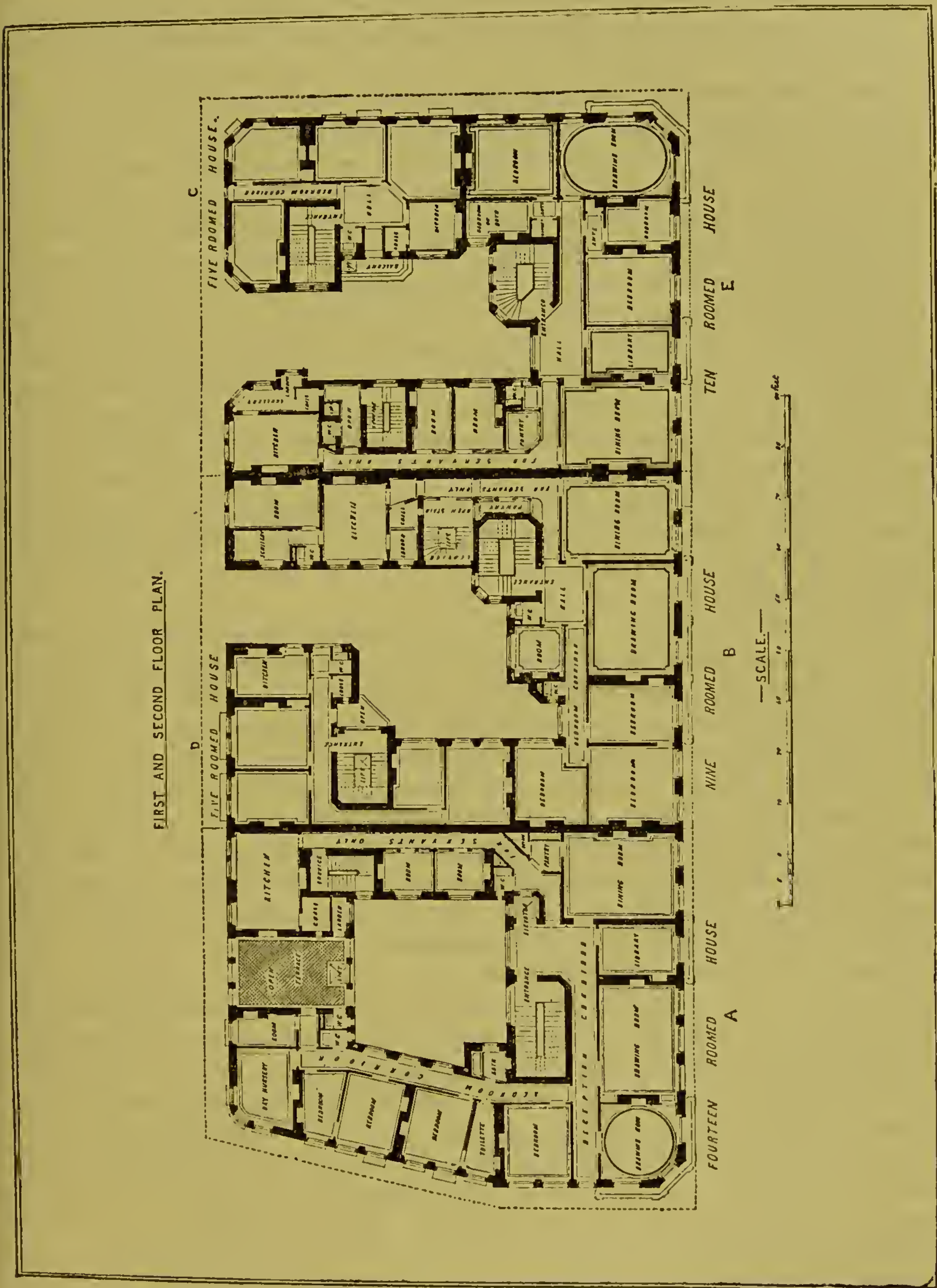
It will be seen by the plan (Fig. 104) that the island is divided into five blocks of shops and houses, separated by two party walls. There are in all twenty-one shops; these are, however, readily capable of enlargement, by throwing one or more shops together.

Perhaps the most conspicuous features in the plan are the three open courtyards, two of which run through from front to back. These courtyards are approached by gateways under the upper floors, and afford access to the several entrances of the houses. The two entrances in Warwick Street are open to the sky, and thus at once an advantage is gained which is entirely wanting to the island as it exists. Again: if the total frontage absorbed under the present system by the private entrances be calculated at three feet per house, it will be found that eighty feet is a moderate estimate. Allowing sixty feet for the five carriage entrances in Mr. White's plan, a clear gain of twenty feet is the result. In seventeen out of the twenty-one shops a mezzanine floor is formed between the shop and the first floor. This floor is intended to serve some useful purpose in connection with the shop, as, for instance, sitting-room, work-room, or lavatory. It would be approached by a small staircase, specially arranged in the shop. In addition to this, each shop would have the basement immediately beneath it, which would afford ample room for storage and other purposes.

The item of sanitary conveniences in the shape of water-closets, etc., does not seem to have been completely thought out. Too often in London shops they are relegated to some dark and unventilated corner of the basement. It would not, probably, be necessary to provide separate accommodation for each of the twenty-one shops. Possibly seven sets, or perhaps less, would be sufficient. It would, however, be absolutely necessary that they should have ample light and ventilation, by direct communication with the external air.

Taking now the upper floors, it will be found that, in all, nineteen houses, containing together one hundred and forty-nine rooms, are arranged on the three floors over the shops. These houses are of four sizes, and have respectively fourteen, ten, nine, and five rooms each.

The largest house, that marked A on plan (Fig. 105), occupies, with its courtyard, in superficial area, nearly one-third of the whole site. It is approached by a staircase opening on to the gateway entrance on the ground-floor. This staircase is, of course, common to all the three floors, the respective principal doors of the houses opening on to the landings. The entrance leads to a spacious hall, in which access is obtained to a hydraulic lift. The principal, or reception corridor, affords access to the four reception-rooms, dining-room, library, and two drawing-rooms. At each extremity of the reception corridor, communication is had with the bed-rooms on the one hand, and the servants' quarters on the other. The family bed-rooms are five



[Fig. 105.—"The Island." Upper Floors. Dwelling-houses in Flats.

in number, exclusive of a dressing-room and the day nursery. At one angle of the courtyard is a bath-room, while at the other end of the corridor a water-closet is placed for the use of the ladies and children. The service corridor leads to the kitchen—a good-sized apartment, in close communication with which is a coal-store. Here an omission must be noted which is certainly at variance with all English

notions of kitchen economy; this is the absence of a scullery. The arrangement and internal economy of the ordinary Parisian kitchen may or may not be infinitely superior to that of an English one; it is, however, essentially French, and depends for its successful management on conditions entirely different from those of an English household. The English plan of subdividing the kitchen department into kitchen, scullery, and larder is one which cannot be discarded or revolutionised by a mere stroke of a pen. Having said this much, it is fair to say that the omission of the scullery is almost the sole fault in an otherwise excellent plan. Opening out of the kitchen on the one hand and the bed-room corridor on the other is a wide, open terrace. This terrace is open to the street on one side, and to the courtyard on the other. It would be supported at each end by columns, and protected by a balustrade, and, as the author suggests, would be the back yard or garden of the house, with the advantage of being under cover. The columns might be decorated with creepers, and flowers and shrubs might be here cultivated with advantage. Here also might be performed such work as knife-cleaning and brushing clothes and boots. The great value, however, of this terrace is the communication it affords between the courtyard and the street, thereby obviating the inevitable tendency to stagnation of the air in the former. At the inner end of the terrace is a lift, for raising or lowering luggage or stores of all kinds. The larder is approached from the terrace, as also is the servants' water-closet.

Immediately adjoining the kitchen is the service staircase, answering of course to the tradesmen's entrance to ordinary houses. Two bed-rooms for servants is all the accommodation given within the limits of each house, but it is suggested that additional rooms in the roof could be readily arranged for this purpose. In an angle of the service corridor, a water-closet is arranged for the male members of the family. Close to, and communicating with, the dining-room, is a small pantry with a cupboard for wine. The pantry is lighted and ventilated only from the passage, and practically is little more than a serving-lobby. The very small amount of space allowed for the storage of wine seems somewhat at variance with English notions. More extended accommodation could, however, probably be provided, if required, in the basement.

There are necessarily some features in this plan new and unfamiliar to the English mind. One of these is the gateway entrance, with the internal courtyard. This, however, as Mr. White justly points out, is an arrangement peculiarly appropriate to the English climate. The gateway would, in fact, act as a covered porch, and people arriving in carriages would be set down under shelter. Nor is this the only advantage of the arrangement. With an internal courtyard accessible from the street to carts and vans, the necessity for trap-doors and coal-shoots in the public pavement is at once abolished. It would, of course, be necessary to pave the gateway and courtyard, either with asphalte or wood, in order to insure a minimum of noise.

The next feature is one of internal economy. It is the necessity that would exist of employing, first a porter, and secondly a servant whose duty would be to attend to and work the elevator. The porter would have to be in attendance in a small office or box, specially arranged for the purpose, and would have to take charge of letters and parcels for absent tenants, give information to visitors, and see that no unauthorised persons gained admission. The cleaning of the

courtyard and staircases would be under his charge, and he would also have to be responsible for the proper disposal of the dust. Here a question arises of great sanitary importance. How is the dust and other refuse of houses on such a system to be disposed of? Clearly the system in use over the greater part of London of storing the house-refuse in bins, where it lies perhaps for weeks, accumulating and decomposing, until the perfunctory duty of the dust-contractor is tardily performed, is out of the question here.

There is no space, happily, for the familiar but unwholesome dust-bin. It appears, therefore, to be necessary that the dust and other refuse should be removed daily. In order to facilitate this, each house would have to be provided with a light iron box, possibly on wheels, of a size which would admit of its being placed on the lift. These boxes would be emptied by the porter every morning into a receptacle of sufficient size to hold their united contents, which would then be wheeled by him to the street, to be emptied into the cart. In many parochial eyes this is a proposal of a revolutionary nature. It is, nevertheless, one which will have sooner or later to be generally adopted. The hydraulic elevator would require the constant attendance of one man, and this would add materially to the rents of the houses. In such a neighbourhood as Regent Street, the rents obtainable would, of course, be high enough to cover an expense of this kind. For houses of a more economical class the apparatus would probably have to be dispensed with.

The above description applies, with certain necessary modifications, to the other houses in the island. Since the paper in which these plans were embodied was written, an enormous pile of dwellings arranged on a somewhat similar plan has arisen on the southern side of St. James's Park, of which it may be said, without much fear of contradiction, that it is the ugliest building in London. It does not need, however, the erection of storey upon storey, piled one upon the other, until the whole looks as if some infantile giant had been playing at building, with some half-dozen or so Gower Street houses for bricks, to illustrate the possibility of adapting this system to English requirements. The aim should rather be to apply the principle in as moderate and economical a fashion as possible, and to keep the vertical height within as small a compass as is compatible with sound financial considerations.

One more point as to building in flats, which applies to all kinds of combined dwellings. The construction must throughout, and in every particular, be fireproof; and particular attention must also be given to the arrangement of the staircases, so as to afford ready and secure egress in case of fire, or alarm of fire.

CHAPTER XVIII.

FIREPROOF CONSTRUCTION AND CONCRETE BUILDING.

Incombustible Materials not Fireproof—Dangers of Iron and Stone—Various Systems of Fireproof Floors—Introduction of Concrete—Concrete for Walls—Lascelles' System of Concrete Construction—Advantages of Concrete.

A VERY important subject for consideration to people dwelling in large towns is the problem of how to construct buildings in such a manner that, in the event of a fire breaking out, the fabric of the building shall be able to stand uninjured a sufficient time to enable the flames to be subdued, and also that it shall not be possible for a fire in one house to be communicated to the houses contiguous thereto.

As described elsewhere, the subject is one which considerably exercised the minds of men in the middle ages, even as early as the twelfth century in England, and measures of more or less efficiency were constantly being taken by the citizens of London in order to check, if possible, the disastrous consequences of the ever-recurring fires. The great fire of London in 1666, while it effectually disinfected the city after the Plague, had a further good effect in that it opened men's minds to the necessity for prohibiting the erection of wooden buildings. Coming down to later times, we have, at the early part of this century, certain regulations regarding party walls, the contact between timber and flues, and the use of timber in external walls, embodied in the first Metropolitan Building Act, which, with additions and improvements in later legislation, constitute all that has been done up to the present time to ensure anything like immunity from fire. That these regulations fall very far short of providing anything deserving the name of fireproof construction is amply proved by the occurrence now and again of fires which, like those of Tooley Street, in 1861, and the City Flour Mills, in 1872, result in the total destruction of large and modern buildings.

Again, the enormous destruction by fire of buildings supposed to be constructed of fireproof materials in Paris during the reign of the Commune in the year 1871, and in Chicago about the same time, proved the now well-established fact, that incombustible materials are not by any means necessarily fireproof, and not only so, but under certain conditions are very much more favourable to the spread of fire than materials ordinarily regarded as the reverse of fireproof.

The old theory that iron and stone, or iron and brick, were combinations which answered every purpose that could possibly be required of fireproof materials is, on examination, found to be perfectly unsound. Both are what, in the ordinary meaning of the word, are known as incombustible materials; both, however, are, with certain limitations, utterly untrustworthy as fireproof materials. Captain Shaw, the chief of the London Fire Brigade, remarks, "When it is remembered that at a temperature of 212° Fahrenheit, or the boiling-point of water, cast iron loses about fifteen per cent. of its strength; that at the temperature of molten lead, 612° Fahrenheit, it has probably no strength at all; and that at a temperature of 2787° Fahrenheit, which is probably much below that of the centre of a large building on fire, it becomes liquid, it seems advisable to supplement this material

with some other more trustworthy in case of heat."* This opinion is amply borne out by the experience of Mr. R. W. Edis, F.S.A., who was in Paris while the fires kindled by the Communists were still burning, and in Chicago during the outbreak of the second fire in that city. Unprotected iron, whether in floors, columns, or roofs, failed everywhere: "it was extraordinary to notice the eccentric forms into which the wrought-iron roofs—notice especially the roof over the Salle des Pas Perdus in the Palais de Justice—had been twisted; wrought iron girders of immense size were turned about by the flames like ribbon, and must in many cases have been heated to almost fusing-point; generally the walls were very considerably damaged by the expansion and twisting of the ironwork in and on them."† The floors of houses in the newer streets were generally of light iron joists about two feet apart, the interspaces filled with plaster of Paris or with brick or tile arches. These floors proved to be fireproof, but in many cases succumbed through the failure of the iron supports.

To quote once more from Captain Shaw: "A fire occurred in a house at the corner of two streets supported altogether by iron columns, and at an early stage of the fire the supports softened, and the house, without a moment's warning, fell completely down, not leaving a vestige of any kind except a small portion of a chimney-breast, to show where it had originally stood."‡ The importance of an instance of this kind to the class of houses with large shop-fronts on the ground floor can hardly be over-estimated.

The conclusion to which these facts, and the numerous careful experiments made of late years, lead us, is that if iron must be used in the construction of a building it should be encased and protected by some material of known fire-resisting qualities. Of these, fire-clay and concrete are the most efficient, and lend themselves most readily to the exigencies of building construction.

Stone as a material for floors, vaults, and staircases is an utterly unreliable material when subjected to even moderate heat. In a great number of buildings in Paris a coarse limestone, known as "Calcaire-grossier," from the great Paris basin strata, is used. Of the action of the flames during the Commune, Mr. Edis (in the paper quoted above) says, "Externally the beautiful limestone, so charming in its capability for delicate moulding and carving, was everywhere calcined and destroyed wherever the flames touched it, the delicate mouldings and carving were licked off, as it were, and the great heat so shattered the freestone walls as to utterly ruin them architecturally, and so calcined them as to render them constructionally unsafe, while the action of damp upon the burnt limestone aided its disintegration and general crumbling away, so as to render it incapable of bearing any weight, and in many cases causing the walls to bulge out and fall." Stone staircases where supported between two walls appear to stand heat fairly well, but when one end only is supported by being tailed into a wall, the effect of heat is to so crack and splinter the stone that the whole staircase falls. The same may be said of stone balconies and floors. Several instances are adduced by Captain Shaw showing the total failure of stone staircases; in one case, that of a fire in a private house in which two lives were lost, a stone staircase which

* Fire Surveys—1872.

† "Notes on the Late Fires in Paris, 1871:" paper read before the Architectural Conference, 1872.

‡ Fire Surveys.

reached from the basement to the landing on the third floor was totally destroyed; a wooden staircase which reached from the third floor to the roof, two storeys above, though burnt, was yet sufficiently firm for the firemen to walk on it after the fire had been extinguished.

There are, of course, exceptions to the general untrustworthiness of stone for use in outside walls. In the course of the discussion on Mr. Edis' paper quoted above, it was remarked that at Chicago the only stone which resisted the action of fire was an artificial material. Ransome's artificial stone is also said to have the power of resisting fire, and specimens of Reigate stone are preserved at the Guildhall which had resisted the great fire of London. The experiment made by Mr. Whichcord on the sandstone selected for the front of the National Safe Deposit Company's premises in Mansion House Street will be referred to later on.

From what has been said above it will readily be gathered that it is possible to have a building formed of materials in themselves incombustible, but which will fail lamentably when the test of fire is applied.

Indeed, it may safely be affirmed that good sound wooden floors and staircases, with the interstices filled with pugging, either of plaster or of slag felt, and the under sides well protected by good plastered ceilings, are, especially if the wood used be one of the harder varieties, far more fire-resisting than many systems of so-called fireproof construction.

It is, however, necessary in many instances, to cover a greater span without intermediate supports than would be possible with a purely wooden construction. In order to meet this difficulty several methods have been devised, all founded upon the fundamental principle that iron when used in fireproof construction must be entirely incased or embedded in a material of tried powers of resistance to fire. Some of these methods will now be described.

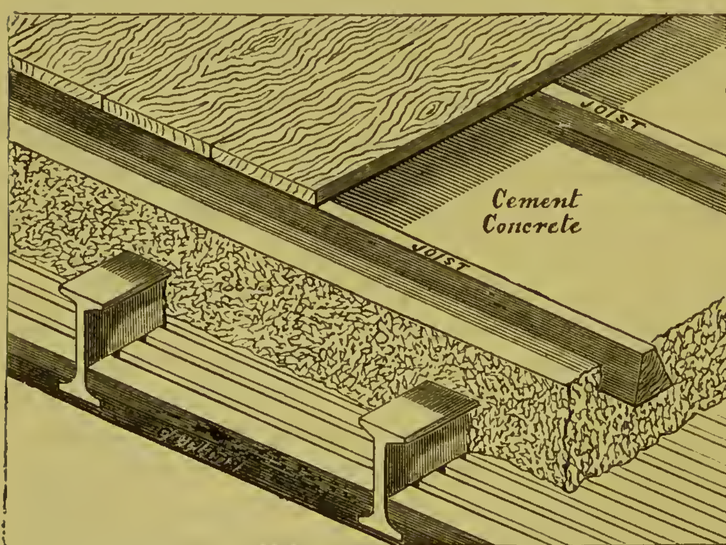


Fig. 106.—Fox and Barrett's System.

Fox and Barrett's system consists of wrought-iron girders placed twenty inches apart, on the lower flanges of which, and at right angles thereto, are placed rough strips or fillets of wood about one inch square and half an inch apart. Concrete is then filled in between the girders and is supported by the fillets. The concrete is brought to a height of three inches above the girders, and can then be finished with cement, or wooden joists and floor-boards laid thereon. If a wood floor is used, the joists are cut to a dovetail section to keep them firmly in their places, and embedded half their depth in the concrete. The under side of the wood fillets forms a key to the plaster of the ceiling (Fig. 106).

The system patented by Messrs. Measures and Co. is a modification of the foregoing system. The iron girders are placed three to four feet apart, and in place of the wooden fillets small iron fillets of this section ⊥, nine inches apart, are placed on the lower flanges of the girders to support the concrete. The advantages of this system over Fox and Barrett's appear to be the absence of wood, and the more complete protection of the iron.

Dennett's system consists of concrete arches, supported on iron girders, arranged in spans of from ten to twelve feet. The concrete used has sulphate of lime (gypsum) for its matrix. The advantage of this material is that it does not lose its cohesive power even when it is raised to a white heat and then drenched with cold water. The floor can either be finished with cement, asphalte, or wood bricks, or joists and floor-boards can be laid down. The arched ceiling can either be exposed to view and finished with a plastered surface, or joists can be fixed to the lower flanges of the girders, and the ceiling lathed and plastered.

Hyatt's system consists of Portland cement concrete, enclosing and strengthened by a network of iron bars and rods. The rods run transversely to the flat bars two and a half inches deep, which are fixed on the walls about two to three inches apart. The rods are a quarter of an inch in diameter. A temporary scaffold is fixed underneath the framework thus formed, and the concrete is thrown on to a depth of about four to five inches. When the concrete has set the scaffold is removed, and the whole is found to be a solid mass.

Thuasne's system is one which had been in use in Paris for some years before the application of wrought iron to the purpose had been introduced into this country. It consists of wrought iron I-shaped girders arched to a rise of about $\frac{1}{200}$, and fixed at a distance of about three feet three inches from centre to centre. At right angles to these girders, and a similar distance apart, are fixed flat iron bars, or inter-ties, the ends of which pass through slits in the wrought iron bands which embrace the girders. The ends of the inter-ties are secured by pins on the inner side of the iron band. At right angles to the inter-ties, and about 9 inches apart, are laid light iron rods, about half an inch square, secured to the inter-ties with wire. Under the framework thus formed, a rough centring is fixed, and coarse plaster of Paris poured in to a depth of 3 inches. The plaster, when set hard, serves to stiffen the floor and also to form the ceiling. To a certain extent, also, it protects the ironwork, but it cannot be said to be a perfectly satisfactory fireproof floor.

The *système Vaux* is a modification of the above, as also are several other systems in use in France.

The system known as "*Fer tubulaire*" (Fig. 107) takes its name from a girder of peculiar construction invented by M. Zorés. This girder is best described as being in section like the letter A minus the triangular top. The girders are placed at a distance of 2 feet 8 inches from centre to centre, and are tied together at intervals of 3 feet by flat bar-iron ties $\frac{3}{4}$ inch by $\frac{3}{10}$ inch bolted to the bottom of the flanges.

Several methods are available for finishing this kind of floor. In the illustration flat arches of perforated bricks are turned across from girder to girder, the spandrils filled in with plaster, and wooden joists and boards laid over the whole. Another method is to fill in between the girders with hollow blocks of plaster 4 inches deep. Iron joists may also be substituted for the wooden joists, and the

ceiling can be formed with small iron laths, leaving the space between the floor and ceiling hollow.

The system patented by the late Mr. Matthew Allen is probably, on the whole, one of the most effective as well as one of the most economical systems yet invented. The result of many experiments in the manufacture of concrete proved beyond a doubt that concrete into the composition of which siliceous materials largely enter is more readily injured by fire than concrete made with a material which has already been burned. In accordance with this fact, Mr. Allen found that by mixing burnt clay, or the slag or refuse from gas-works, with Portland cement, he obtained a concrete, the fire-resisting properties of which were very great indeed. He also found that his material possessed the further very important property of great tensile strength. The fire-resisting capability of concrete thus made proved indeed to be so great that it has been used with entire success as a lining for furnaces.

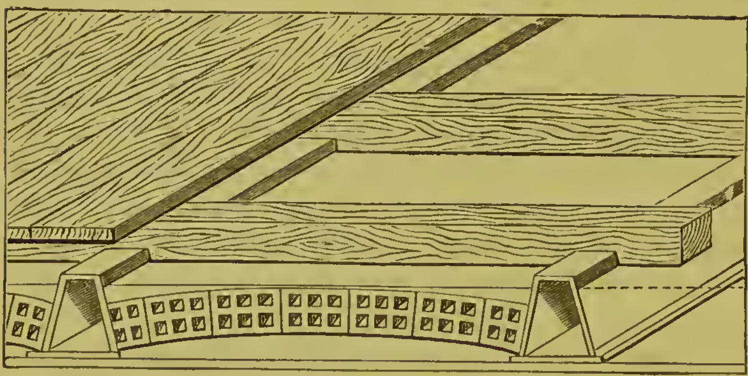


Fig. 107.—Fer Tubulaire.

The principle upon which Mr. Allen worked in devising his fire-proof floor was not that the concrete should be supported by and subsidiary to wrought iron girders, but that the iron-work and the concrete should mutually support each other, and form one homogeneous whole. To carry out this principle, he adopted a system of a light iron framework, or skeleton, which he clothed with concrete as the bony skeleton of an animal is clothed with flesh.

The framework consists of bars 3 inches deep, 1 inch thick, placed on edge from wall to wall 2 feet apart; at right angles to, and across these bars are placed ½-inch iron rods, also 2 feet apart. Thus a network is obtained with meshes 2 feet square. Underneath this network a temporary scaffold is erected and the concrete thrown in to a depth of 7 inches. When the concrete is sufficiently set the scaffold is removed, and the floor is ready to receive whatever finish it is desired to put upon it.

Mr. Allen carried his concrete construction to such a degree of perfection that he not only made floors, but also doors, windows, lintels, and staircases of the same material.

The system devised by Mr. Whichcord (late Pres. R.I.B.A.) in the construction of the National Safe Deposit Company's offices in Mansion House Street, London, is one which, though applicable chiefly to floors of very large span, should certainly be noticed in any description of fireproof construction. In the building in question a large area had to be floored over without any intermediate wall, and with only two or three columns. It became, therefore, a matter of necessity to use deep wrought-iron girders, and hence any system of embedding iron ties in concrete was out of the question. The problem to be solved was how to clothe these iron girders in such a manner that they should be absolutely safe from the effects of fire. The

solution was found in encasing the girders with fire-clay. The girders thus encased were subjected to very severe tests, the result of which proved perfectly satisfactory and the system was applied to the iron columns as well as the girders. In the construction of this building another difficulty presented itself. Under the terms of the purchase of the land, the material for the exterior facing was to be either marble, granite, or stone, brick being prohibited, except for inner walls and backings. It became therefore necessary to select a stone which should be capable of resisting not only extreme heat, but extreme heat alternating with excessive moisture. The stone ultimately selected was a sandstone from quarries near Wrexham, known as "Minera" stone. A cube of this stone, 6 inches square, was placed in the centre of a furnace, and left there for an hour and a half. It was taken out quite perfect and plunged into cold water without being in the least degree cracked or otherwise injured.

The system invented by the late Mr. Hornblower, of Liverpool, has not been long introduced. The principle of this system is the combination of iron, fire-clay, and concrete. Rolled iron joists 6 inches deep are placed at intervals of 2 feet, each joist being contained in a fire-clay or terra cotta tube, and the interstices filled with concrete; in the intermediate spaces between the joists are placed hollow tubes of fire-clay, and the whole floor is then filled in with concrete, till the total depth reaches 12 inches. The advantages which this system presents are:—first, the absolute protection afforded to the iron by the tubes and the concrete; and secondly, the combination of three elements of strength, iron, terra cotta or fireclay tubes, and concrete. The construction of a floor by this system is very clearly shown by Fig. 108. The upper and under surfaces of the fire-clay tubes are grooved to afford a key to the ceiling and floor.

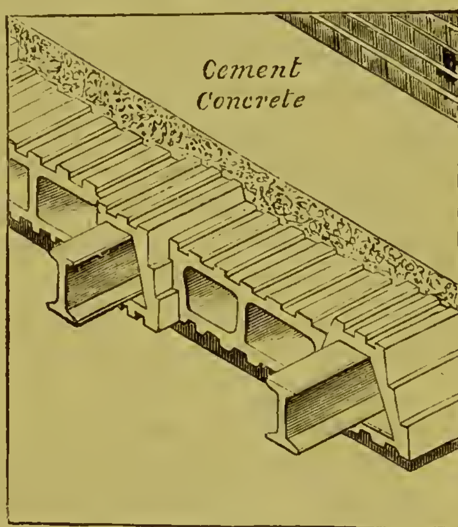


Fig. 108.—Hornblower's System.

The bearing-power of such a floor as that described is said to be two tons per square yard with a span of 18 feet from wall to wall. This is of course much greater than would be needed in any dwelling-houses, where $1\frac{1}{2}$ cwt. per square foot is the weight usually allowed for; but in ball-rooms, or rooms where a large number of persons would be likely to assemble, it would not be excessive. For lesser spans, and for ordinary dwelling-house floors, joists of less depth and a modified form of tube are used. The floor can be finished in any way desired; parquetry, mosaic, or tiles, can all be laid on the upper surface of the concrete, or the floor may be finished with a smooth surface of Portland cement. The ceiling also admits of any amount of plaster decoration, and without the chances of damage incidental to a ceiling fixed to a wood floor with wood laths.

Although primarily intended for floors, the system is obviously capable of being applied to walls and other purposes.

A system has been devised by Mr. Butler for rendering an ordinary wooden floor fireproof by incasing wooden joists in terra-cotta or fire-clay slabs, and concrete or plaster.

Evans and Swain's system consists of ordinary wooden joists of any uniform depth and any thickness, two or three inches being preferred, placed side by side close together, and brought laterally into contact by bolts or spikes. As a protection to the underside, flat-headed nails are driven in, and the surface rendered with a thick coat of plaster. Thus a fireproof floor is formed almost wholly of a combustible material. Solid stairs are formed on this system, and are certainly far more secure in case of fire than stone ones would be.

CONCRETE CONSTRUCTION.

The use of concrete in some form or other for building purposes is of very ancient date. The ancient Egyptians made the foundations of their temples with a concrete of stone and marble cemented together. So also in Greece, the foundations of the Acropolis, and the central inclined plane of the Propylæa, were constructed of a species of rubble-work, which may be termed concrete. Perhaps a more interesting instance of the use of the material is that of the ancient buildings of Mexico, the foundations of which were constructed either of pebbles and broken stones, or of broken stones and clay firmly compacted.* Vitruvius, in his famous work on Architecture, written in the first century of the Christian era, mentions a method in use amongst the Romans of building rubble or concrete walls, faced on both sides with masonry. This he calls "*Emplecton.*" In Palladio's first book of Architecture, published at Venice A.D. 1520, will be found directions for forming walls in this fashion, and also for building walls of concrete, which he calls "*Reimputa,*" or coffer-work, and which he says "were made by the ancients by taking planks laid edgeway, according to the thickness of the walls, filling the void with cement and all sorts of stones mingled together, and continued after this manner from course to course." The process is in fact identical with that commonly in use at the present time in forming concrete walls.

Until within comparatively recent times, however, the use of concrete was practically, in this country, restricted to foundations; and, indeed, for that purpose it only superseded timber almost within living memory. Notwithstanding the fact that in 1760, Smeaton, the engineer of the Eddystone lighthouse, recognising the value of the material from the way in which he found that at Corfe Castle it had stood the test of centuries, employed concrete in locks and other works, the use of it did not become by any means general until the beginning of the present century. The interstices between the piles of Waterloo Bridge were filled with a concrete of Kentish rag-stone and liquid mortar. This was in 1811. A little later the towers of Millbank Penitentiary failed, owing to the uncertain nature of the soil on which they were built; they were underpinned with concrete. From that time to the present concrete has been the invariable material for foundations.

Before proceeding to describe the practical applications of concrete to constructional purposes, it will be well to give some slight description of the nature and composition of the material.

Concrete then, as its name implies, is the intimate admixture of different substances, one being the aggregate, or material to be cemented, the other the matrix, or cementing medium. The aggregate most commonly used is gravel, from which the finer parts or sand have been separated. This forms at best a very poor

* "Essay on the Nature and Properties of Concrete." G. Godwin, R.I.B.A. Transactions, Vol. I. 1835.

ingredient, as the nature and form of the stones afford but slight hold to the cement or lime. The best aggregates are stone, burnt ballast, broken pottery, breeze or coke, and slag. They all require crushing or grinding, it being a point of the utmost importance that the pieces of stone or other material should be angular, and not round; the first-mentioned varying greatly in value, some stones being of too friable a nature to make good concrete. The matrix is either lime or cement. For ordinary foundations lime answers every purpose sufficiently, but for work requiring great strength or delicacy of finish, Portland cement is the best material to be had, and, in fact, is indispensable. Much depends upon the quality of the cement, and it would appear that old cement, while taking longer to set, in the end sets harder than fresh cement.

The invariable custom, until within recent times, in forming concrete foundations was to erect a staging some considerable height above the trench, and from this elevation to pour in the concrete. The idea was that the impetus thus given would tend to consolidate the ingredients and insure their homogeneousness. Recent experience, however, tends to upset this theory, and the custom is now merely to wheel the material to the trench, and gently tip it into the required position, where it is carefully rammed down. In all cases care should be taken to lay each course of concrete horizontally, and of a uniform thickness of not more than 12 inches throughout.

Considerable attention has of late years been paid to the formation of walls in concrete. Several systems have been devised for the purpose, most of which consist of filling in with concrete the space between some kind of framework formed for the purpose. The primary object of most of these systems, that of reducing the cost of house-building, has as yet scarcely been attained to the extent that was anticipated; while the difficulty and great cost of altering a house built of solid concrete, would obviously be considerable. Another drawback is the necessity of finishing, except where the expense of sgraffito or other forms of decoration can be incurred, with a uniform surface of cement; a dull cold grey colour being eminently unsuitable in this grey climate to the exteriors of houses.

A more important property of concrete as a material for external walls of dwelling houses, is its porosity, and at the same time its power of resisting saturation by water. In the investigations made by Professor Pettenkofer, of Munich, it was found that while bricks made from clay were completely soaked with water in from 9 to 12 hours, it took from 55 to 190 hours to saturate a slag brick. These slag bricks are simply a form of concrete in which the aggregate is the slag from iron furnaces.

The element of permeability to air is a matter well worth attention in this country, where well-built houses are frequently made as air-tight as possible. The following extract from Mr. H. Reid's treatise on concrete is interesting, as having a direct bearing on the subject of health, and also as taking a somewhat different line from that usually taken by authorities in this country. :—

"An hospital at George-Marien-Hutte was built during 1870—71 of these slag bricks. It was opened in 1872, and in June, 1876, the medical superintendent testified to its salubrity. There is accommodation within its walls for thirty-two patients, twenty-eight being comfortably placed in four spacious wards and four in separate small rooms. The walls are hollow, having an air space of $2\frac{1}{4}$ inches, and so successful is the result that no smell of hospital air is observable even in

the rooms where offensive suppurating wounds are treated. All these advantages are derived from 'the extremely advantageous porosity of the slag bricks.'"

How far this opinion is correct it is impossible, without further investigation, to say. If, however, the slag bricks really have anything like the qualities attributed to them of permeability to air and non-permeability to water, they are obviously a material of very high value.

LASCELLES' SYSTEM OF CONCRETE CONSTRUCTION.

Perhaps the most novel application of concrete to constructional purposes is that invented by Mr. Lascelles. By the use of various ingenious devices he has made it possible to build a house, into the constructive parts of which, and even to a large extent into the decorative parts also, not one single atom of timber need enter.

The object sought to be attained by Mr. Lascelles was not, however, in the first place, fire-proof construction so much as an economical damp-proof wall. As Mr. Lascelles remarks :—"In an ordinary brick or stone house, the strength of the wall is out of all proportion to the weight it has to carry. The main thing thought of is the damp. The bulk of the material is increased, until it is thought the wet will never find its way through, although it sometimes does in spite of all precautions."

There can be no question of the superiority of a hollow wall to a solid one for dwelling houses; the difficulty to be overcome is the increased cost and bulk necessitated by the former kind of construction.

The method devised by Mr. Lascelles for forming a hollow wall that should be at once economical in material and in space may best be described as consisting of two thin skins of concrete fixed on either side of a supporting framework. The framework, which may be of wood, iron, or iron embedded in concrete, must, of course, be of a sufficient strength to support the various floors and superstructure. The skins need be of sufficient thickness only to withstand the ordinary wear and tear likely to occur. Starting then with these conditions, Mr. Lascelles erected a pair of cottages (Fig. 109), the outer framework of which was composed of upright wooden studs, 4 inches by 3 inches, 3 feet apart, and on this were fastened with ordinary wood screws, slabs of concrete composed of four parts of coke to one part of cement, with two rods of iron one eighth of an inch in diameter placed diagonally in the centre of each slab. The inner faces of the slabs were finished with lime and sand, the wooden framework showing in the rooms. Two defects made themselves known in these cottages. The first was that in damp weather, when the rooms were full of moist air, on the lowering of the temperature outside, the moisture was deposited on the walls in the same way as it is under similar circumstances and from the same causes deposited on the window glass. The other fault was, that the party walls proved to be no protection whatever in the matter of sound passing from one side to the other.

The remedy was found in each case to consist of doubling the concrete skin so as to form hollow walls. At the same time it was found practicable to reduce the thickness of the slabs to one inch.

A more extended application of the system is shown by a house erected by Mr. Lascelles at Croydon, and illustrated in Fig. 110.

The whole of the external walls of this house are constructed of the concrete

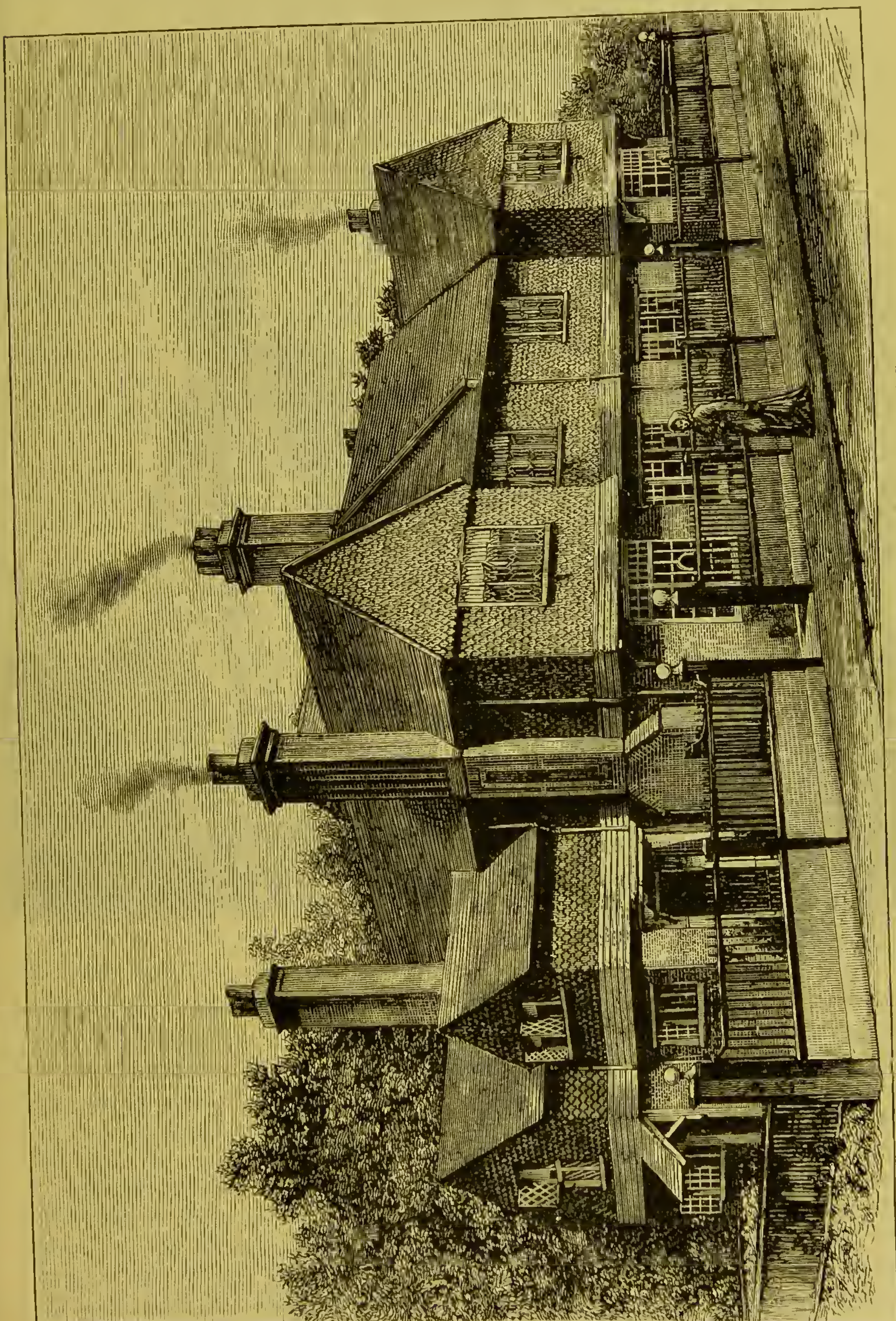


Fig. 109.—Pair of Cottages Built with Concrete on Mr. Lascelles' System.

slabs described above, and, as will be seen from the sketch, it is finished outside in imitation, partly of brickwork and partly of weather tiling.

The floors also are all formed of concrete slabs. The ground floor, where no cellar exists, is floored in the following manner :—at intervals so placed as to catch the corners of four slabs, brick piers nine inches square are built, and on them are laid the slabs. The joints between the slabs being made good with cement, the whole surface is plastered over with red cement, thus presenting an

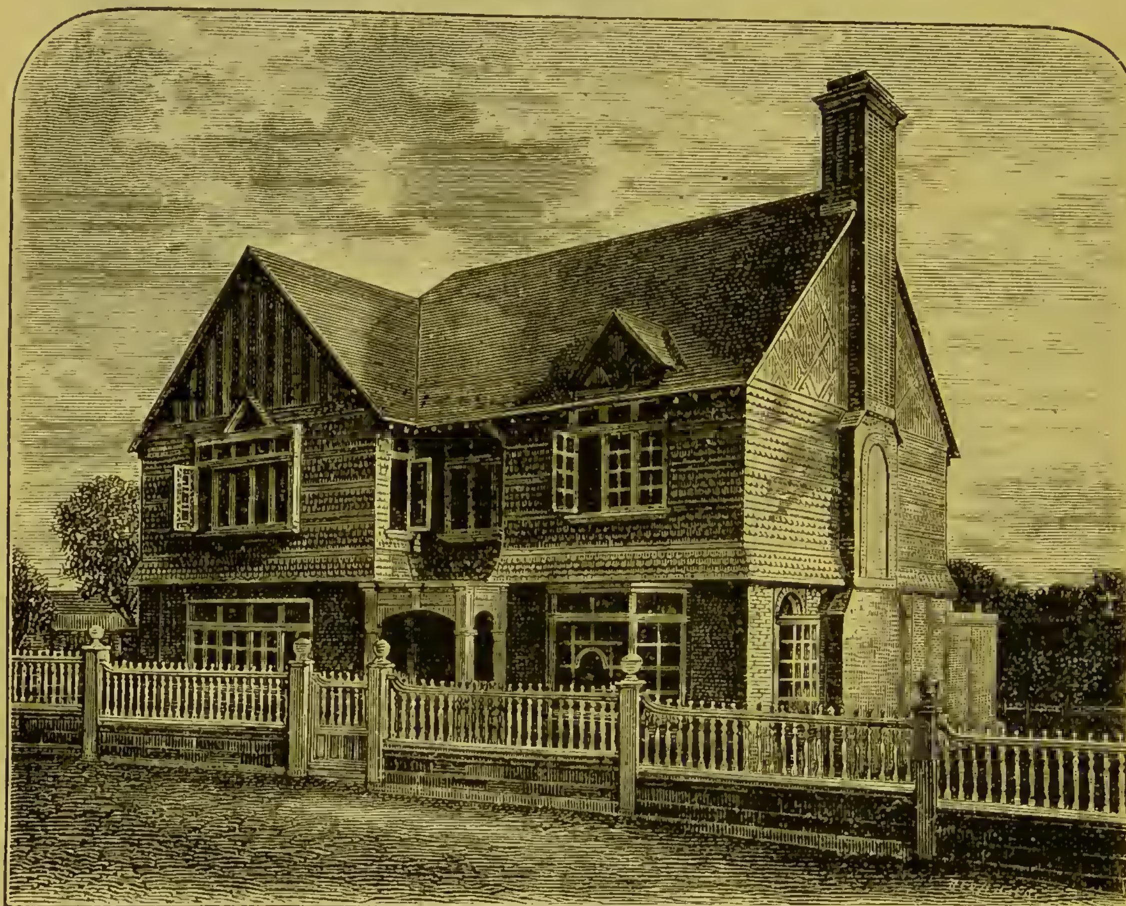


Fig. 110.—Concrete House at Croydon.

unbroken face over the whole floor. The space under the floor is utilised in an ingenious manner for the admission of warmed fresh air into the room above. The air previously to entering the space under the floor is passed over a series of hot-water pipes which are used to heat a fernery. The floors of the upper rooms are made of the same kind of slabs, finished as to their upper surfaces in a similar manner. There being no plaster ceiling, the under sides of these slabs were visible in the ground floor rooms, and it became necessary, therefore, to treat them in an ornamental manner. The whole of the floor timbers being also visible were wrought and moulded, and on the under side of each slab where visible between the joists was an ornament in low relief cast in the concrete. A floor formed in this way possesses two distinct merits, the first being that the surface is entirely unbroken, and there are, therefore, no crevices or cracks

through which dust or dirt of any kind could accumulate as in an ordinary boarded flooring. The second is that it is entirely waterproof; liquid spilt on it could not percolate through to the underside. What is not quite so certain is whether a floor formed in this way would be satisfactory as regards the transmission of sound. It would, of course, be a simple matter to form a plastered ceiling in the ordinary manner, and to fill in with pugging between the joists.

The house is roofed with Staffordshire tiles laid in the ordinary way. A method of using concrete for roofing purposes has yet to be devised; all attempts hitherto having failed on account of the shrinkage.

A special and valuable property of concrete properly made is the ease with which ordinary wood screws can be inserted. This being so there is no difficulty in forming door and window-frames, sills, cornices, chimney-pieces, and in fact everything which can be made in stone or brick, and a great many things hitherto regarded as only to be made of wood. A recent and valuable application of concrete, suggested by Mr. Alfred Waterhouse, A.R.A., is that of bricks to fasten joinery, to supersede wood bricks.

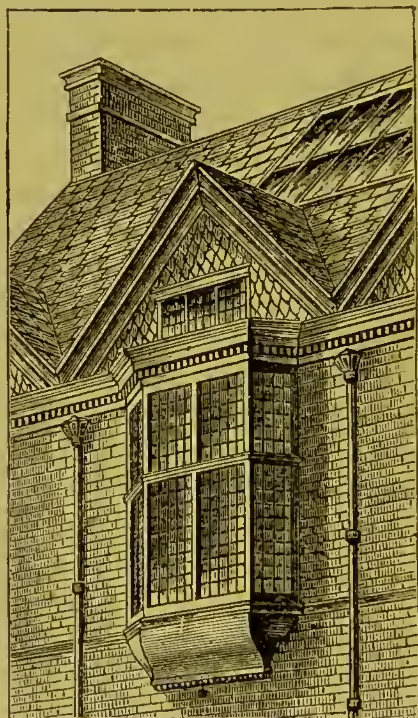


Fig. 111.—Concrete Bow-window.

Casting ornament in concrete has been already alluded to. The material has now been brought to so high a degree of fineness of texture that really delicate ornament can be produced. It seems odd to mention picture-frames in connection with so rough a material as concrete; it is however a fact that small frames with delicate arabesque ornament in low relief have been successfully made with this useful material. Some ornamental chimney-pieces of very effective character have been produced in the same material.

In Fig. 111 is an example of the application of concrete under circumstances which precluded the employment of wood. In a studio designed by Mr. R. Norman Shaw, R.A., it was desired to erect three projecting windows, in order to secure certain special conditions of light, in the manner shown in the sketch. It was found that if constructed of wood the window would infringe the provisions of the Metropolitan Building Act. To get over this difficulty, and yet retain the form and character of the windows, the frame-work was constructed of concrete, strengthened with light iron rods.

A notable specimen of the application of concrete was exhibited at the Paris Exhibition of 1878. A house is a prominent position in the Rue des Nations, was erected by Mr. Lascelles from the designs of Mr. R. Norman Shaw, R.A. The whole of the various parts of the house were made in London, and erected by French workmen under the superintendence of an English foreman. On the wooden framework were fixed concrete slabs one inch thick fastened with screws; on these slabs were fixed, in courses to resemble brickwork, thin tiles of the

sizes of bricks and half bricks. The character of the architecture is what is usually known as Queen Anne; the front being divided vertically by pilasters into three unequal bays with a window in each, the wider one being in the centre. On the ground floor is a projecting window corbelled out, and having on one side the door and on the other a narrow window. Moulded string-courses immediately over the first floor windows, and at the sill level of the second floor, form, with the pilasters, panels in which elaborately carved slabs are inserted. The whole is crowned with a bold projecting cornice enriched with egg and tongue moulding and modillions. The pilasters are crowned with quasi Ionic caps with wreaths, and at the first floor level a balcony with turned balusters projects along the entire face. The whole presents the appearance of a carefully designed brick house of the early part of the last century. With the sole exceptions of the door and the window sashes, the whole of the exterior is constructed of concrete.

The advantages of entire concrete construction for such purposes as hospitals, and infirmaries attached to schools, and other buildings of a kindred purpose, are manifestly very great. And this is more especially true with regard to buildings intended or likely to be used for the treatment of diseases of an infectious nature. The advantage in the latter case is twofold; for not only would a building constructed wholly of concrete be absolutely washable in every part, but it could be so thoroughly cleansed and disinfected, that it might with perfect safety be occupied by patients suffering from a totally different disease within a few hours of its vacation by fever patients. The complete and effectual disinfecting, and thorough cleansing of such a building, would be a matter of comparative simplicity. There would, for instance, be no difficulty in raising the temperature by artificial means to a point of sufficient heat for disinfecting purposes. Again, for the purpose of mere cleansing it would be possible to pour into the house, and over every part of its interior, a powerful and continuous jet of water from a hose pipe.

CHAPTER XIX.

SMALL SEMI-DETACHED AND TERRACE HOUSES—HOME HOSPITALS.

The usual style of Small Houses—Semi-detached Houses at Ealing—at Watford—at Midhurst—Terrace Houses in Telford Park—Small Houses at Queen's Park, Kilburn—Home Hospitals.

THERE is probably no class of dwelling-house which stands in more need of improvement in arrangement and construction than the small surburban house of a rental value of from twenty pounds or less to fifty pounds a year. The increased value of all land available for building within reasonable distances of large commercial or manufacturing centres, restricts the area of each plot of ground to a frontage line of from fifteen to twenty feet, and a depth of from fifty to a hundred feet. Upon a site of this shape there is but little scope for variation in the disposition of the rooms. It is in the details of planning that every conceivable error is commonly made—and in dealing with this class of house it should be remembered that a fault once made is repeated with religious strictness in all the scores of houses that are built to one pattern. The need for attaining a very high degree of excellence in a plan which is to be the pattern from which some hundreds of houses are to be built will be apparent to all.

An additional reason for insisting upon the greatest possible amount of care in planning houses of the class now under consideration is, that the people who inhabit them—clerks, professional men, and others—are practically compelled to take what they can get, and are powerless to improve what they know to be bad. To take an ordinary house of perhaps £30 per annum rent, in any one of the now thickly populated suburban districts which a few years ago were country lanes and fields: the front door is at the side, and opens on to a narrow passage three feet wide at the most, which, when the door is shut, is in a state of almost absolute darkness. Perhaps, however, the builder has bethought himself of this point, and formed over the door a glass fanlight. This fanlight, however, being the only and obvious means of ventilating the hall and staircase, is hermetically sealed. The first door to be approached is that of the front parlour; a pleasant room enough, with a bay-window, with its array of that best of all decorations, natural flowers. The attention, however, is soon attracted to certain disfiguring stains on the walls, rising in unequal patches from the skirting; and which, being obviously damp, connect themselves instinctively with a certain mouldy smell perceptible in the room. The cause of both smell and stains is not far to seek; it is—no damp-proof course, and no concrete under the floor. The ultimate effect will undoubtedly be dry-rot in the floor timbers, and destruction of paper after paper; until at last the enemy is attacked at the root, and at great cost the damp-proof course is inserted, the ground under the floor is removed, and concrete laid down.

Behind the last-named room, and possibly opening into it with folding doors, is a smaller room, about which there is nothing particular to be remarked, except that its smaller size is necessitated by the additional width required for the stairs and passage at the side, while its outlook at the back is narrowed by the projecting block of domestic offices.

In this projection is situated the kitchen; which, being the room that by reason of the heat of the fire, and the necessity for its being in use during the heat of summer as in the depth of winter, stands most in need of an ample supply of air and ventilation, is considerably smaller as to area, and some two feet lower in height than the rest of the house. Here, from innumerable crevices in boards and plaster, swarms of black beetles, emerging at night time, pervade every accessible spot. A wholesale slaughter now and then does not tend to improve matters by leaving hosts of bodies of defunct insects to the process of decay. A solid floor of concrete and wood-bricks, such as has been described in a preceding chapter, would provide a lasting and not inexpensive remedy for this abominable pest.

Adjoining the kitchen a small dark and damp recess contains a sink, and is called the scullery; while side by side, and with carefully arranged facilities for ventilating the one into the other, are the servant's water-closet and the larder; and at a few feet distance, the dust-bin, with its complement of bones, decaying vegetables, and other refuse.

Upstairs will be found the bedrooms, with, now-a-days, not unfrequently the bath-room. The size of these rooms and their position cannot well be varied, but care has been taken to render them as pervious to rain, and as susceptible as possible to changes of temperature, by building the outer walls only 9 inches thick, and by omitting any non-conducting material between the ceiling of the upper floor and the slates on the roof.

The staircase, squeezed into as small a space as possible, consistently with getting up at all, is so full of winding steps, and so steep, that one trembles for the chances of the poor little ones who will have to toil up and down the steep ascent. The utter disregard of the possibility of a house of this kind being ever inhabited by children is a curious and noteworthy fact.

The faults described above, together with other sins of omission, such as the neglect to supply cupboard room, and the utter disregard of the simplest possible rules of sanitary science in the drainage arrangements, are repeated again and again, notwithstanding the complaints which assail the builder on all hands.

At the root of all this lies the system of granting building leases at as high a ground-rent as possible. An owner of "eligible" building land sees his way to making an increased income by letting it for ninety-nine years on building leases. His interest apparently is confined to obtaining as large a rent as possible for the land without troubling about the class of building to be put on it, so long as the land is sufficiently covered to secure his rent. Practically this is so, but surely the best interests of the landlord are not alone to secure his present income, but to provide for posterity property which shall not come to them as worn-out ruins. Surely, too, the ownership of land ought to carry with it some responsibility, and the landlord ought to consider it incumbent upon him to take some pains to insure that the houses erected on his land shall be at all events fairly sound and healthy. Assuredly the tenant whose circumstances will not permit him to do much for his own protection, has a right to expect that he shall not be denied that protection which a paternal government affords to his poorer brother the artisan.

Of the illustrations of houses of the smaller class of suburban dwellings, Figs. 112 to 114 represents some moderate sized semi-detached houses at Ealing, designed

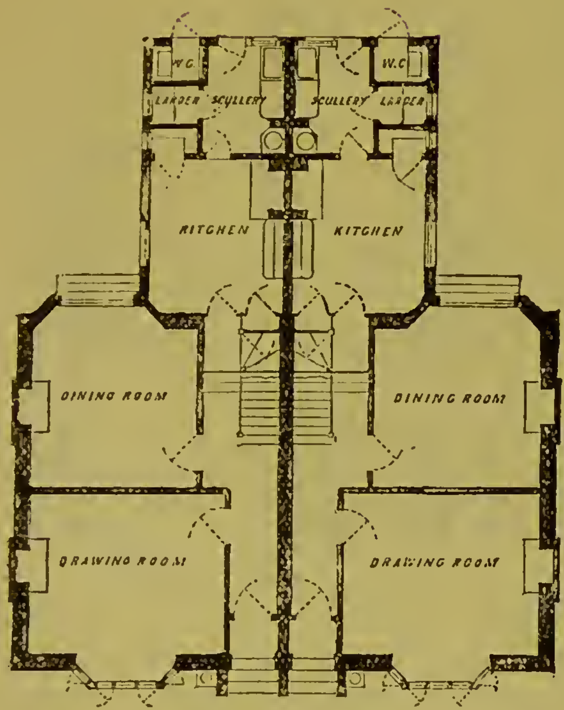


Fig. 112.—Ground Plan.

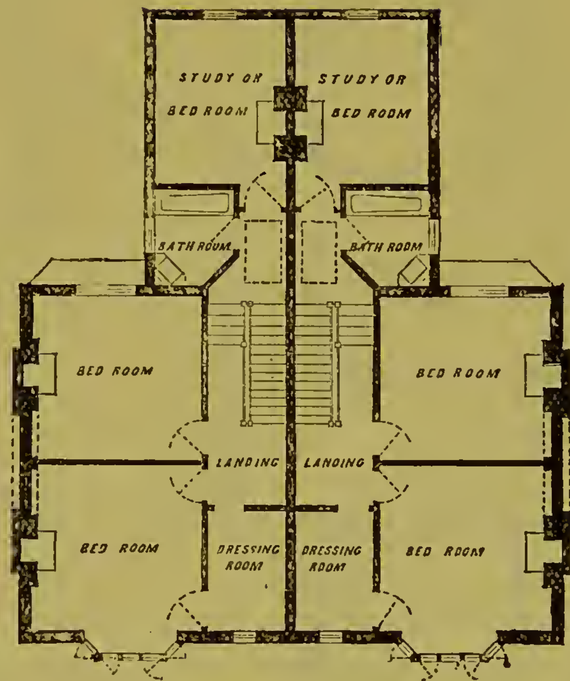


Fig. 113.—First Floor Plan.

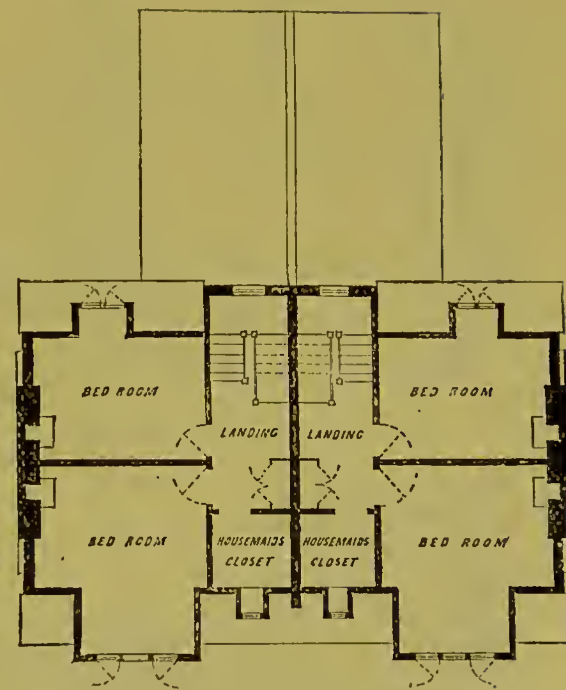


Fig. 114.—Second Floor Plan.

Semi-detached Houses at Ealing.

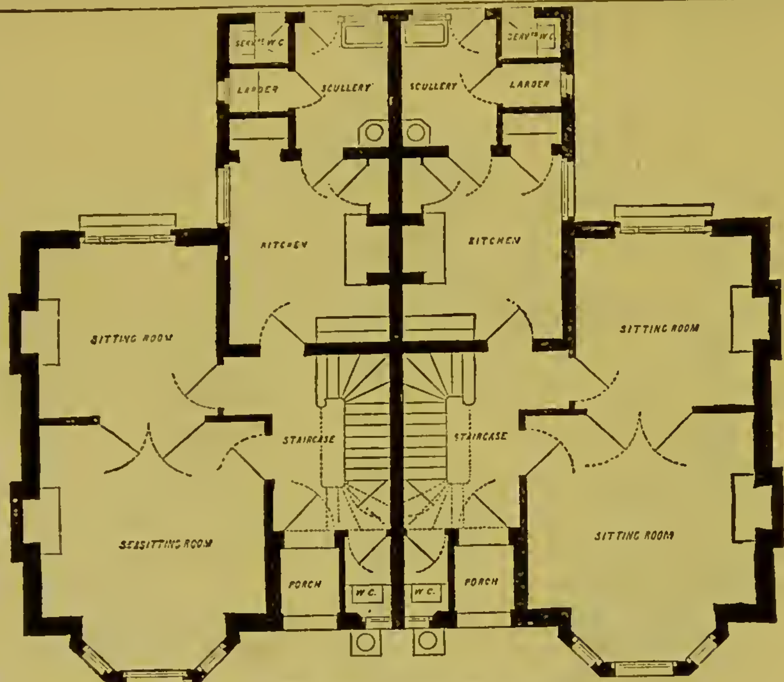


Fig. 115.—Ground Plan.

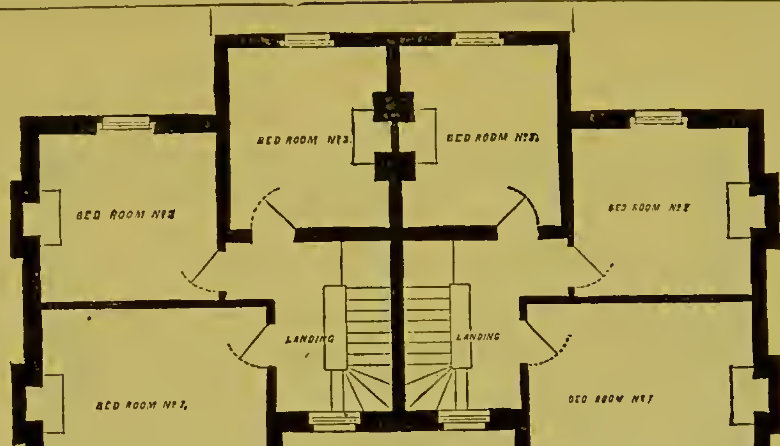


Fig. 116.
First Floor Plan.

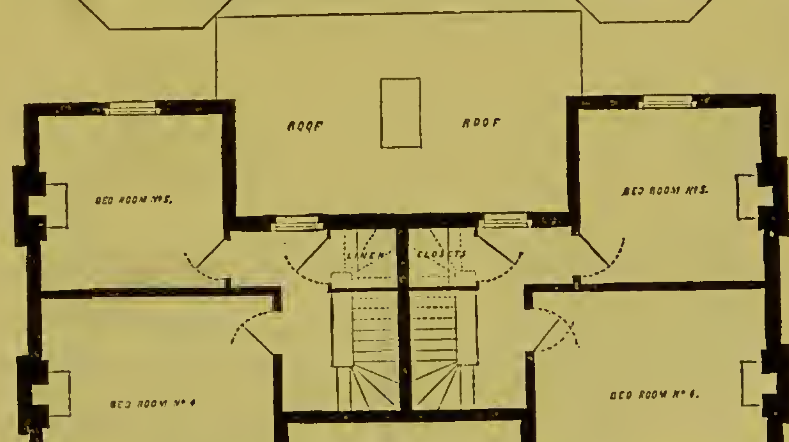


Fig. 117.
Second Floor Plan.

HOUSES AT WATFORD.

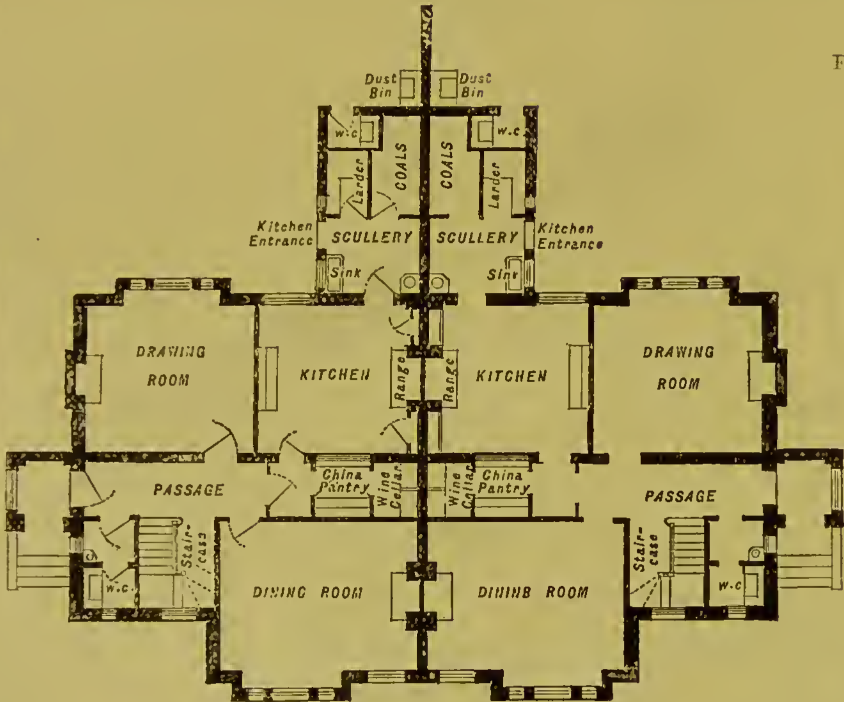
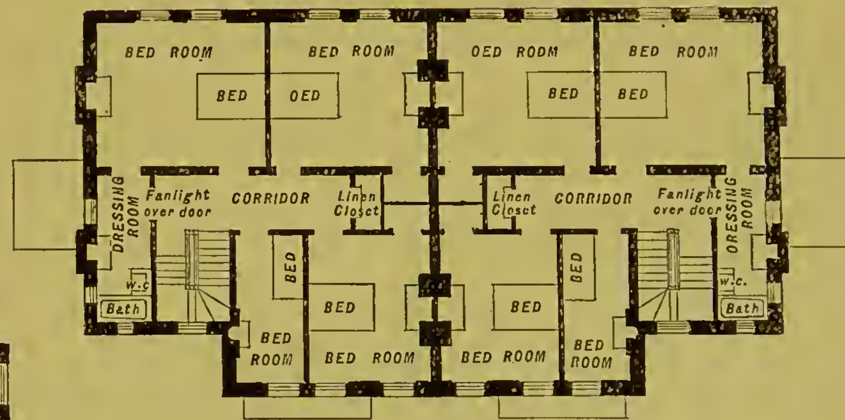


Fig. 118.—Ground Plan.

Fig. 119.—First Floor Plan.



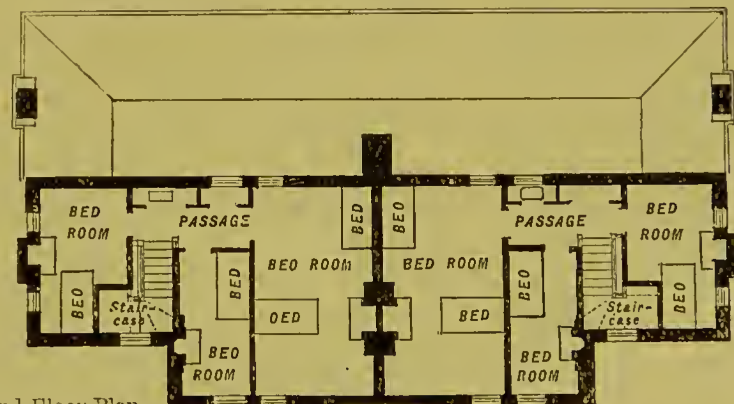


Fig. 120.—Second Floor Plan.

HOUSES AT WATFORD.

by Mr. W. J. Green, F.R.I.B.A. The rental value of these houses is about £45 a year. There are, as will be seen from the plan, two sitting-rooms and five bed-rooms, making with the kitchen what is commonly known as an eight-roomed house. It will be observed that although in close proximity to each other, there is no possibility of the larder being contaminated by foul air from the servants' water-closet. A small coal-cellar is provided under the front entrance hall. Noteworthy points of careful planning are the way in which the bay window of the dining-room is arranged, the almost complete absence of winding steps in the staircase, and the provision of a small room in the roof with a window for the cistern, &c.

The next plan (Figs. 115 to 117) is of semi-detached houses at Watford of somewhat smaller dimensions and different arrangement. The staircase is brought nearer to the front entrance, by which means an appearance of greater size is given to the entrance, while in reality some economy of space is effected. The rain-water from the roof is collected into a large tank in the garden of one of the houses, and each house is provided with a pump connected with this tank.

Figs. 118 to 120 show a pair of semi-detached houses also designed by Mr. Green, of larger dimensions than either of the last, being what are known as ten-roomed houses. These houses were erected as a speculation, and it was thought desirable to attain as imposing an appearance in the front as possible. Accordingly, the plans are so arranged that by placing the staircase in front and bringing all the upper floor also to the front, an appearance of greater size is obtained than is actually the case. The arrangement of lobby to the kitchen, the wine-cellar, and pantry, is a very original and carefully worked out detail of planning. So also, on the first floor, the wardrobes and linen-closet are just those minutiæ of planning which are systematically ignored by the speculating builder, but which make all the difference between comfort and discomfort in a house of this class.

Figs. 121 to 120 show a pair of semi-detached houses erected at Midhurst from the designs of Messrs. W. F. Meakin and Son. Though not strictly suburban houses, there is nothing in the arrangements which would be inconsistent with their being in the suburbs of any large town. They contain six rooms each, and would probably let in the suburbs of London for a rental of about £40. There is no particular feature to comment upon in the planning, which is straightforward and simple.

Figs. 124 to 126 are plans for small terrace-houses of about £40 a year rent, designed by Mr. E. J. Tarver.* The frontage of each plot being only eighteen feet, the houses are necessarily small. The most, however, has been made of the space available, and the result is certainly a most convenient and compact little house. Points deserving of special mention are: first, the position of the bay-window in the drawing-room; by placing it out of the centre of the room the wall space on the fire-place side is unbroken, and the result is that the light is better distributed, and an effect of greater space is gained. Next, the position of the fireplace in the angle of the dining-room is quite the best that could be chosen, as it allows more space for moving round the table; a very valuable gain in so small a room. The provision of a small pantry with a sink is a useful one, and one, moreover, seldom thought of by the designers of this class of house. Up-stairs, by an ingenious arrangement of the staircase, the back room, usually very small, is here a fair-sized room.

* The designs for these houses have all been registered by the proprietors.

The design of the houses is a free and picturesque treatment of ordinary materials, such as brick, stone, and tiles; the principal object in view being to obtain a pleasing and attractive appearance with simple and durable materials.

The three plans of houses in Queen's Park, Kilburn, are typical examples of a kind of house for which in suburban districts there is a very large demand. They

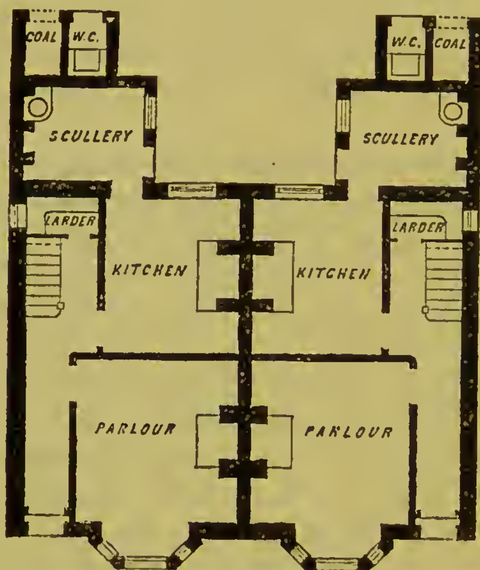


Fig. 121.—Ground Floor Plan.

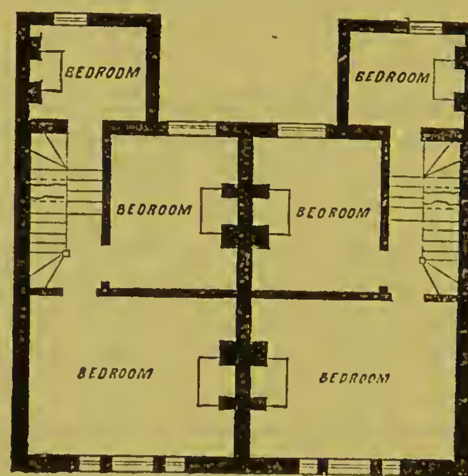


Fig. 122.—First Floor Plan.

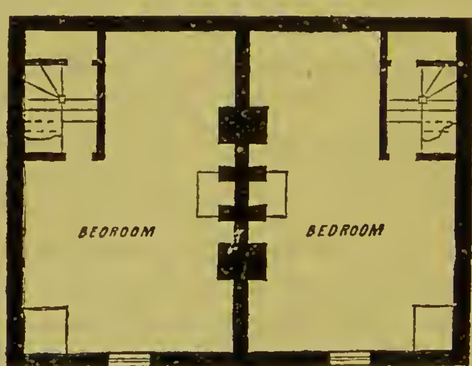


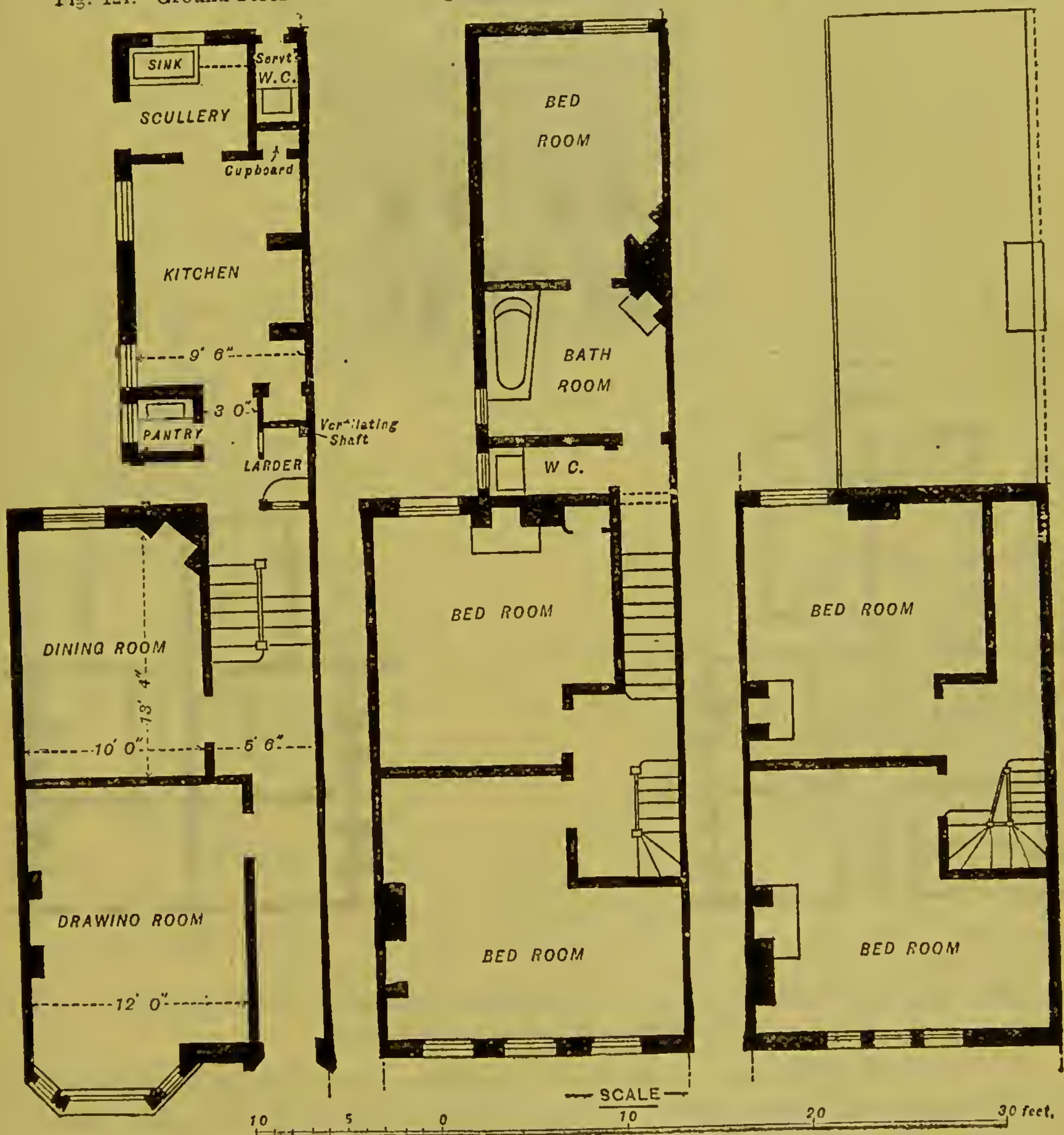
Fig. 123.—Second Floor Plan.

HOUSES AT MIDHURST.

are erected on an estate belonging to the Artizans', Labourers', and General Dwellings Company, of about 75 acres in extent. The object sought by this company is to provide well-built, convenient, and healthy dwellings for the working classes, the houses being small, and let at weekly rents ranging from 6s. to 13s. 6d. To attain this object at a remunerative outlay, it is of course necessary to select sites at such a moderate distance from town as will not render the cost of travelling to and fro greater than the class of tenants who are to occupy the houses can afford. The great facilities offered in the way of workmen's trains with reduced fares by

several of the railway companies running out of London, have greatly increased the demand for the class of houses now under consideration; and while in the more central parts of London, where land is so dear, it must be a necessity to build large and lofty blocks of dwellings for the industrial classes whose means or occupation will not permit them to live far away from their work, there can be no question

Fig. 124.—Ground Floor Plan. Fig. 125.—First Floor Plan. Fig. 126.—Second Floor Plan.



Terrace Houses in Telford Park.

that for those whose avocations enable them to live a short distance away the small two-storey dwelling is by far the better one in every sense.

The estate from which the illustrations are taken is laid out with spacious roads, the width of which is increased by the houses being set back within fore-courts. Trees planted in the fore-courts impart a cheerful and pleasant aspect to the roads, and by a judicious variation in the types of the houses, the dead and dreary level of uniform ugliness usually so successfully attained, is here happily avoided.

The number of houses on the estate, when it is all developed, will be 2,162, being at the ratio of about 27 per acre. To provide for the education of the large number of children necessarily implied by these figures, large Board Schools have already been erected or are being erected solely for the occupants of the estate.

In point of construction, the objects sought to be attained by the company may perhaps best be explained by an extract from a report by the architect to the estate. "In laying out an estate for a company whose operations are so important,

Fig. 127.—Elevation.

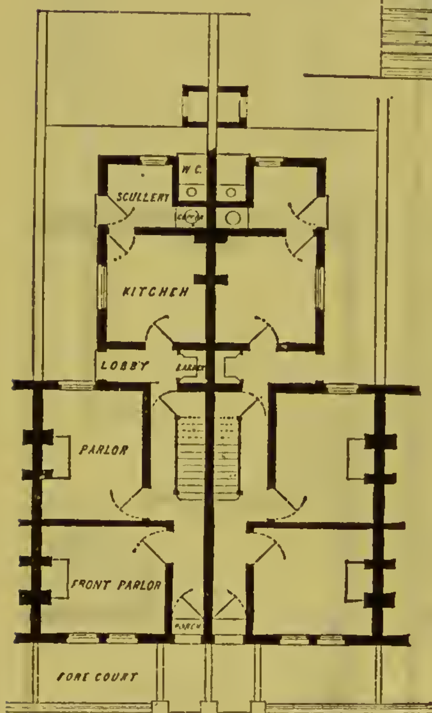


Fig. 128.—Ground Plan.

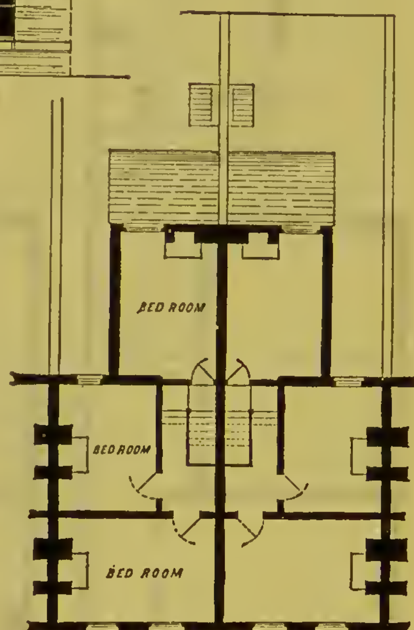


Fig. 129.—First Floor Plan.

SCALE

SECOND CLASS HOUSES IN QUEEN'S PARK.

. . . . . . it is necessary to do so in as attractive and liberal a form as possible without waste and extravagance; it is also highly necessary to have due regard to the rapid growth of sanitary science, and to endeavour to comply with, and to anticipate if possible, its many requirements, and especially those of them which will, I believe, in a few years be considered by the population at large as absolutely necessary for habitable dwellings, not only as regards the actual sanitary fittings and appliances of the houses themselves, but also as regards their actual construction from the foundations upwards, and also more especially as regards the light and air space with which they are surrounded."* It is in the application of these principles

* Report to the Chairman and Directors of the Artizans', Labourers', and General Dwellings Company, by Rowland Plumbe, F.R.I.B.A. Kindly lent by Mr. Plumbe with the sanction of the Board.

that the real difficulty of constructing houses of this class at a remunerative outlay lies. The ordinary speculative builder, who looks to obtain a high rate of interest for his money, as a matter of fact systematically ignores all these considerations, and by so doing attains his object.

Fig. 130.—Elevation.

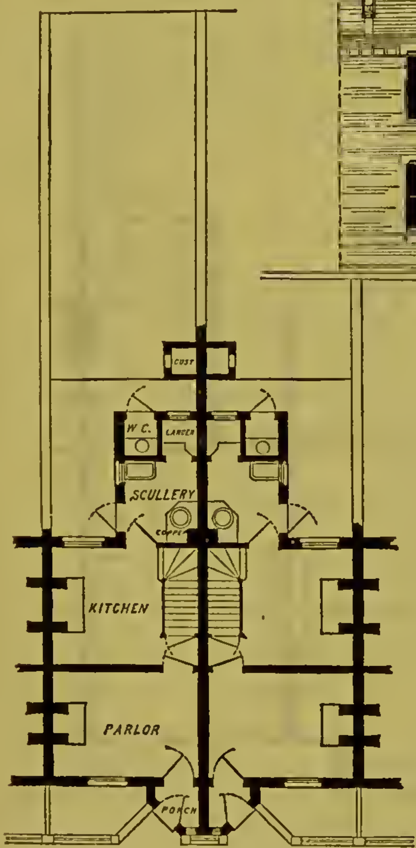


Fig. 131.—Ground Plan.

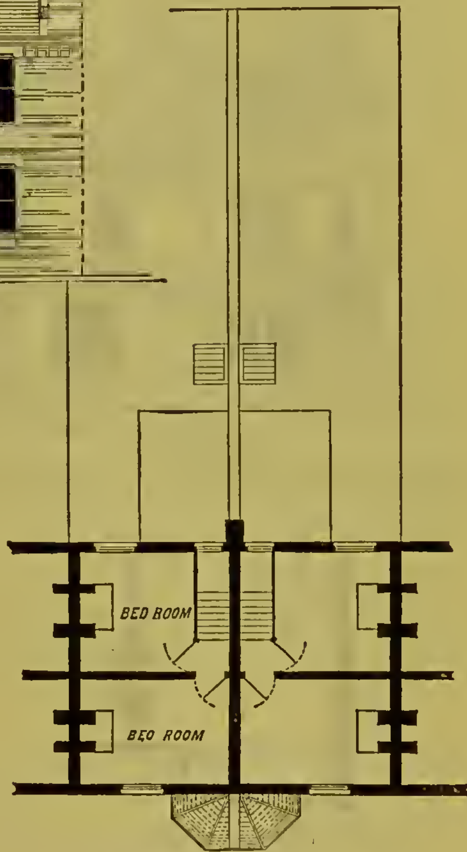
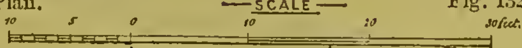


Fig. 132.—First Floor Plan.



SMALL HOUSES IN QUEEN'S PARK.

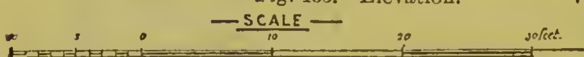
There are five different classes of houses on the estate, the rents of which are as follows :—

First-class house	. . . . .	13s. 6d. per week.
Second do.	. . . . .	10s. 6d. ,,
Third do.	. . . . .	9s. 6d. ,,
Fourth do.	. . . . .	8s. 6d. ,,
Fifth do.	. . . . .	6s. 6d. ,,

The type of the second-class houses is illustrated in Figs. 127 to 129. The ground floor contains entrance passage with a small covered porch, front and back parlours, (11′ 0″ × 10′ 0″, and 9′ 0″ × 13′ 2″ respectively), lobby entrance to yard, small larder, kitchen (9′ 0″ × 10′ 0″), scullery, with copper in recess, and water-closet. In the back-yard, and detached from the house, is a dust-bin of sufficient size, and provided with a proper cover. The upper floor contains three bedrooms (14′ 3″ × 10′ 0″, 9′ 0″ × 12′ 3″, and 9′ 0″ × 13′ 3″ respectively).

Figs. 130 to 132 represents the fifth, or smallest, class of house. The frontage of the plots on which these houses are built being only 13′ 0″, the space is not sufficient to allow of a passage being taken off the front room; a small porch is therefore arranged which, while sheltering the parlour and maintaining the desired privacy, adds a feature of interest to the front of the house. With the scullery, there are but four rooms in all, and the staircase is entered out of the kitchen. The larder, in point of position, is certainly preferable to that in the second-class house.

Fig. 133.—Elevation.



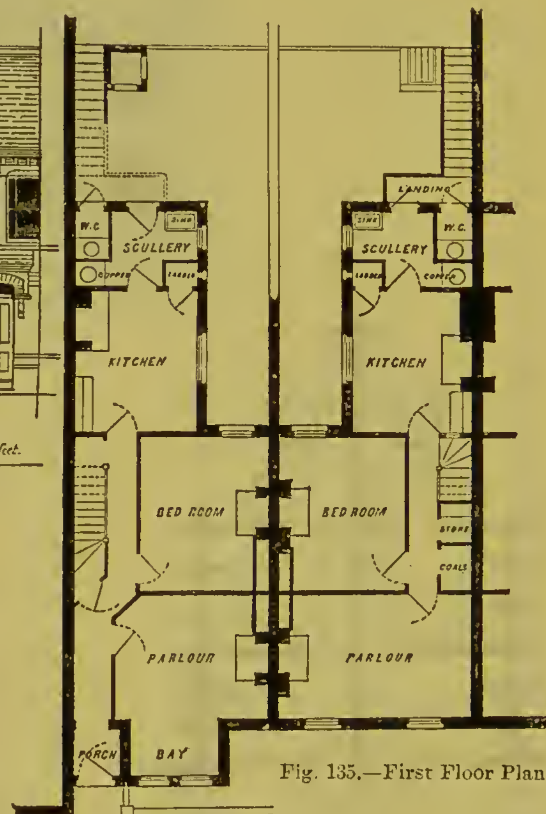


Fig. 135.—First Floor Plan.

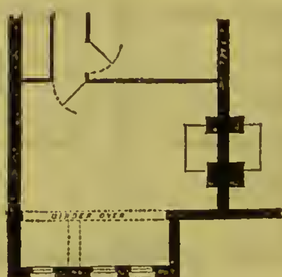


Fig. 136.—First Floor Plan of Turret.

Fig. 134.—Ground Floor Plan.

SMALL HOUSES IN FLATS.

The third specimen of house, illustrated by Figs. 133 to 136, is on a somewhat novel system. It is supposed by some persons who have had experience of this class of houses, that in such a house as the second-class one there is a certain amount of facility afforded for tenants to crowd their own families into too small a space; in order to let some of their rooms as lodgings. It is conceivable, for instance, that the back parlour might be turned into a bedroom, and the two upper bedrooms let off. Within reasonable and proper limits there could be no possible objection to this; but there is no doubt that with a certain class of tenants there would be overcrowding, and it is to obviate this that the houses now to be described have been devised.

These houses are built in flats; each house containing in itself two separate and distinct tenements, self-contained in every particular.

There is a common porch and entrance-passage, and the entrance to the upper flat is at the foot of the staircase which gives access to it. On each floor is a parlour, bedroom, kitchen, scullery, larder, and water-closet, a small coal-store being

arranged on the landing of the upper floor. The parlour of the upper floor is larger than that of the lower floor by the width of the passage. A flight of steps from the scullery of the upper floor affords access to the common dust-bin and back-yard. The rent of each flat is 5s. 6d. to 6s. 6d., or the whole house 10s. 6d. per week, An advantage in these houses not shared by the others is that in each case the w.c. is approached under cover; the balcony affording protection to the ground floor. while the balcony itself is roofed over on the upper floor.

The finishings and fittings of the houses are all necessarily of the simplest nature. The aspect both of the estate generally, and of the houses in particular, is pleasing and attractive; while, by the introduction of special features, such as turrets or projecting windows, at the corners of roads and other prominent positions, the inevitable monotony of long rows of houses of one size and character is greatly relieved.

HOME HOSPITALS.

The necessity has long been felt for some kind of hospital accommodation which should be available for the large number of persons whose circumstances place them beyond the scope of charitable aid in sickness, but whose dwellings are unsuitable or incapable of affording the comforts and special conveniences necessary in a protracted illness. And this applies to illnesses of all kind, and not alone to diseases of an infectious nature. In the diseases of the latter class (scarlet fever, small-pox, &c.), the necessity for isolation is imperative: it is, in fact, enforced where an outbreak occurs in a house occupied by more than one family; and it seems difficult to understand why isolation should not be equally enforced in houses where there is no efficient means of isolating the patient from the other inmates, notwithstanding the fact that those inmates are all part of one family. To do this, however, would require a far greater amount of hospital accommodation for infectious fevers than at present exists.

The first effort in the metropolis to supply the need for a hospital for paying patients has been made by the Home Hospitals Association at Fitzroy House, No. 16, Fitzroy Square. An ordinary town house, built in the early part of the present century, has been adapted to the purposes of the hospital, and every effort has been made to overcome the difficulties presented by the arrangements of a house designed for the ordinary requirements of a family. The idea sought to be realised in all the details of the establishment is that of a home, the hospital feeling being carefully eliminated.

The house is entered by a broad, well-lighted entrance-hall, on the right of which is the dining-room, which is fitted up in every respect like the dining-room of a private house. Behind the dining-room is a bed-room, appropriated to the purpose of an accident ward. The furniture in this room, which is in every respect similar to that in all the other bed-rooms, consists of a brass-mounted iron bedstead, with a spring mattress and feather-bed, a chest of drawers, cabinet for books, &c., washstand, with double set of crockery, cupboard for bed-pan, &c., towel-horse, writing-table, and chairs. The wood used is ash, French-polished, and the furniture is simple and tasteful in design. The floors are stained and wax-polished, and a few Persian rugs are laid about them. The walls are papered and varnished. The windows are fitted with the patent imperial sash apparatus, by

means of which an ordinary double-hung sash is made to open on centres, or to slide up and down as required. A light screen, of the same wood as the furniture, is provided; and by a simple contrivance the whole of the panels, which are made of cretonne, on light iron rods, can be lifted out, and fresh panels fixed into the frame-work of the screen. At the back is a waiting-room and secretary's office. On the landing over the last rooms, and between the ground and first floors, are the matron's sitting-room and a small ante-room.

The upper floors are entirely occupied by bed-rooms. On the landing between the first and second floors is a bath-room and water-closet. The bath is of porcelain, and is fitted with hot and cold water, and has a shower-bath attached. The water-closet apparatus is Bostel's Brighton closet, with a water waste-preventing apparatus attached. This apparatus is worked by a pull-down handle, and is so contrived that the whole of the contents (two gallons) of the apparatus is discharged whether the handle is held down or not. The seat is hinged, as every water-closet seat should be, and the rim of the basin, the lead safe, and all the other parts, can be cleaned out whenever occasion requires. There is another water-closet and a slop-sink, and a bath-room, on the third floor. The linen-room is on the top floor, and in it are placed the hot water circulating cisterns to the baths and supply taps. The cisterns are in a room in the roof, and easy access is afforded to them by a ladder from the top landing. The basement contains the kitchen offices, servants' hall, and nurses' sitting-room. The nurses' bed-rooms are in a building at the back, originally constructed for stables.

For all these purposes the best has had to be made of an existing house, and arrangements which could be much improved upon in a specially-designed building have had to be left very much in their original condition. Wherever it has been possible to do so, the wall surfaces have been made washable by the application of varnish. By means of windows and air-bricks, free currents of air have been supplied to all parts of the house. The stoves are in most cases the original ones, and have no special features beyond those found in ordinary dwelling-houses.

Special attention has been paid to the drainage of the house. The main drain runs from the yard at the back, through the basement passage, to the sewer in the Square. At each extremity is a man-hole, with a hinged cover for access to and examination of the drains, which at these points are formed of half-pipes bedded in concrete. Fresh air is admitted to the drain by two inlets in the front area, and the soil-pipe is continued up above the highest part of the roof as an extraction shaft. At the man-hole in the back area is fixed a stand-pipe, with hose attached, by means of which the whole of the drains are flushed out twice a day. All the sink wastes, overflow pipes, and bath wastes are made to discharge into open iron-heads or into gully-traps. The drainage from the back building, in which the nurses' bed-rooms are situated, is, from structural reasons, taken out to the back. A similar contrivance for flushing, and similar ventilation, is applied to this system of drains.

The air of comfort and homeliness which pervades the whole establishment is very satisfactory, and it is to be hoped that the Association may find their project succeed sufficiently to enable them to erect an entirely new Home Hospital which shall answer their requirements in every way more completely.

The whole of the alterations were designed and carried out by Mr. Ernest Turner, F.R.I.B.A.

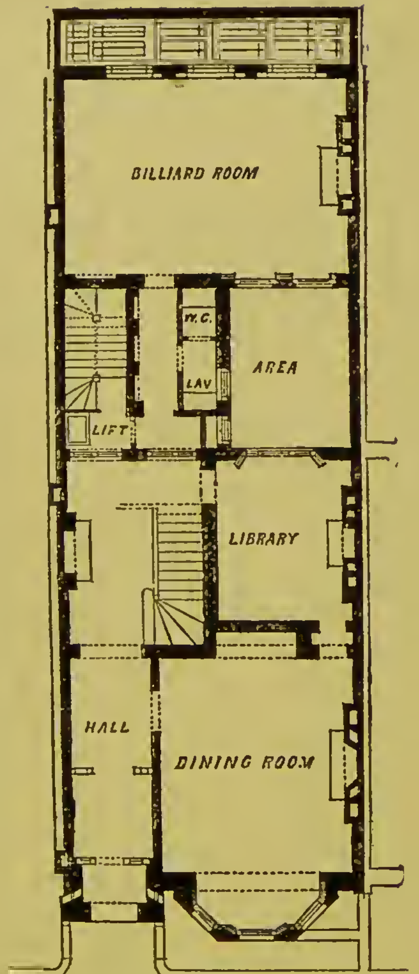


Fig. 137.—Ground Floor Plan.

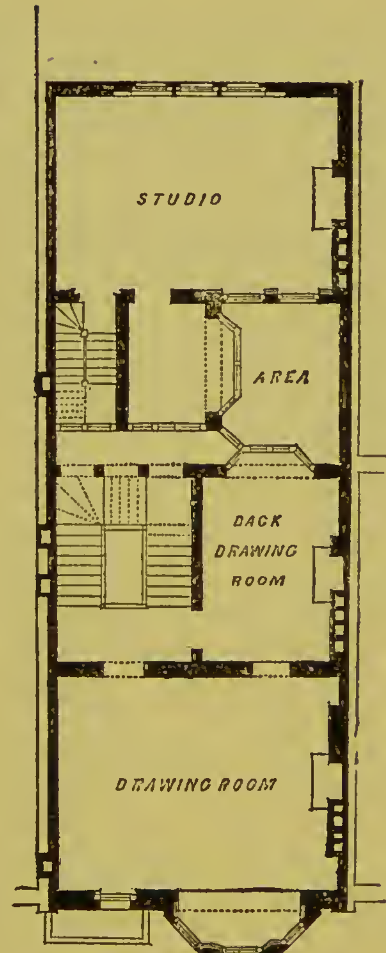


Fig. 138.—First Floor Plan.

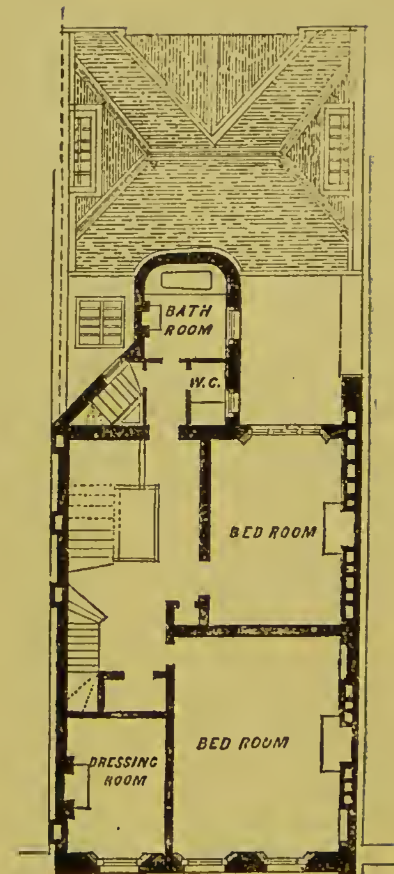


Fig. 139. Second Floor Plan.

— SCALE —

10 5 0 10 20 30 40 50 feet

Terrace House in Upper Berkeley Street.

CHAPTER XX.

LARGER TERRACE, SEMI-DETACHED, AND DETACHED HOUSES.

Terrace House in Upper Berkeley Street—Detached House at Hampstead—Converted Corner House at Brighton—Detached House at Hampstead Hill Gardens—Detached House at Ealing—Semi-detached House at Balham—Detached House at Woking—Bungalow at Birchington-on-Sea—House for School at Brighton.

HOUSE IN UPPER BERKELEY STREET.

THIS house (Figs. 137 to 139) was erected from the designs of Mr. Robert W. Edis, F.S.A., F.R.I.B.A., and as a specimen of a London house in a West-end street, presents some noteworthy features. In designing the ground floor an endeavour was made to depart from the traditional arrangement of London houses, in which the main staircase is directly opposite the visitor as he enters. Ample light, a necessity so all-important but so frequently neglected, has been provided everywhere, even in the basement, a matter of no small difficulty in a large house of this kind, where so much of the ground must perforce be covered.

The basement is devoted to the servants' offices; an arrangement all but inevitable in London streets. The kitchen, of ample size and lighted by wide skylights the whole length of one side, is at the back, with the scullery and larder in immediate proximity. The latter is lighted and ventilated from a large open area, on the other side of which is the butler's pantry. To the front are the servants' hall and the footman's room. Wine-cellars, beer-cellars, closets, knife and boot cleaning room, and coal-cellars are provided on this floor, while close to the back staircase, which extends from the basement to the second floor, is the lift, which ascends to the level of the ground floor.

Separate water-closet accommodation is provided for the male and female servants.

The ground floor is entered from a projecting porch from which access is obtained to a lobby, and from thence to the hall and staircase. The dining-room occupies the front of the house, and has a spacious bay window to the street, and a recess for a specially-designed sideboard.

A door of communication is made between the dining-room and the library, thus enabling the latter room to be used as a serving-room when occasion requires.

Partly over the kitchen, and approached by a corridor from the inner or staircase hall, is a large billiard-room, in close proximity to which a water-closet and lavatory are arranged.

On the first-floor the front drawing-room occupies the whole frontage, the bay window of the floor below being continued up to this room. Communicating with the front drawing-room is a smaller room, which is also provided with a bay window, and from which access is obtained to a conservatory and studio behind. Thus the whole floor can be used as one suite of rooms, whilst separate access to the studio is preserved from both best and back stairs.

The upper floors are occupied with bed-rooms, bath-rooms, &c. The latter, as also the housemaid's closet, is fitted with hot and cold water supply.

By a simple arrangement of flues, the chimneys of the best rooms are all swept from the basement, and provision is made for ventilation by carrying up ventilating flues with the smoke-flues. The drains are arranged carefully, and are disconnected and ventilated.

As has been remarked above, the important matter of lighting was carefully attended to in planning the house. Another point of almost equal importance, that of avoiding spaces, internally and externally, calculated to promote the accumulation of dust and dirt, was not lost sight of. From a sanitary point of view nothing can be worse than the innumerable ledges and corners, dark and inaccessible, which abound in most London houses, new as well as old, and which seem purposely arranged to harbour refuse and dirt, often not of the most savoury character, and always, be it remembered, liable to decay. It is no exaggeration to say that in a London house all unnecessary angles, ledges, and corners to which the light does not penetrate, should be, as far as possible, done away with. At no season of the year is a London house overburdened with sunlight; there can therefore be no possible excuse for neglecting to provide window-space the most ample and well distributed possible.

From a heating-chamber in the basement, hot water is supplied by pipes to warm the conservatory, billiard-room, and passages.

Externally the house is designed in a phase of what may be called Free Renaissance, carried out in red brick. The sashes are glazed with plate glass, and by the adoption of this and other modern improvements an endeavour has been successfully made to adapt the style to modern requirements, instead of resuscitating old forms and old features which our forefathers would have gladly changed had they had the benefit of modern improvements.

The cost of the whole was about £7,000.

HOUSE IN FITZJOHN'S AVENUE, HAMPSTEAD.

Figs. 140 to 143 illustrate the plans of a house recently erected in Fitzjohn's Avenue, Hampstead, from the designs of Mr. George Aitchison, A.R.A., at a cost of about £5,000.

It affords an example of a suburban villa residence—a class which does not receive the benefit of an architect's skill in the design as often as could be desired. The estate on which it is erected has only been laid out for building purposes within the last few years; and the greatly-increased value of the land in the locality has had the effect of somewhat curtailing the extent of frontage allotted to each house. As a consequence most of the houses on the estate, including the one now under consideration, are planned with the domestic offices in a half-sunk storey or basement. This arrangement is greatly assisted by the natural slope of the ground, there being a gentle rise from the Swiss Cottage to the top of Hampstead Hill.

In the centre of the front is the principal entrance, the steps to which are covered by an enclosed and projecting porch. The kitchen entrance is at the side.

The basement storey contains a good billiard-room, 25 feet by 17 feet 7 inches, with a bay-window in addition. In connection with this room, and approached by a lobby, is a lavatory and water-closet. The kitchen, 16 feet 8 inches by 16 feet 6 inches, with a small scullery adjoining, and a store-closet, are placed together

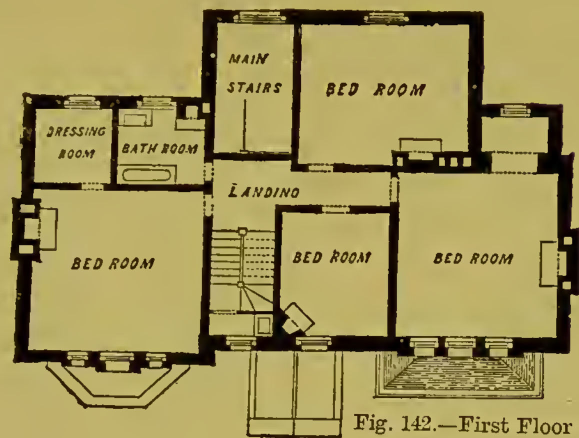


Fig. 142.—First Floor Plan.

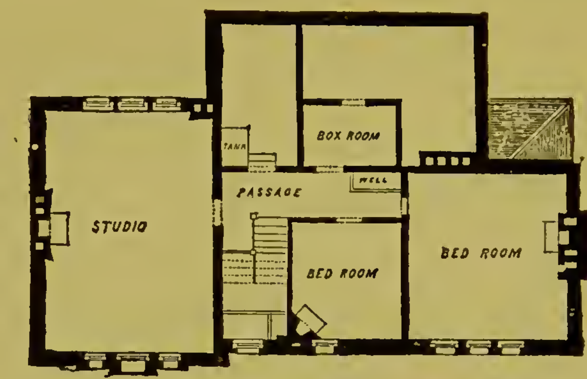


Fig. 143.—Second Floor Plan.

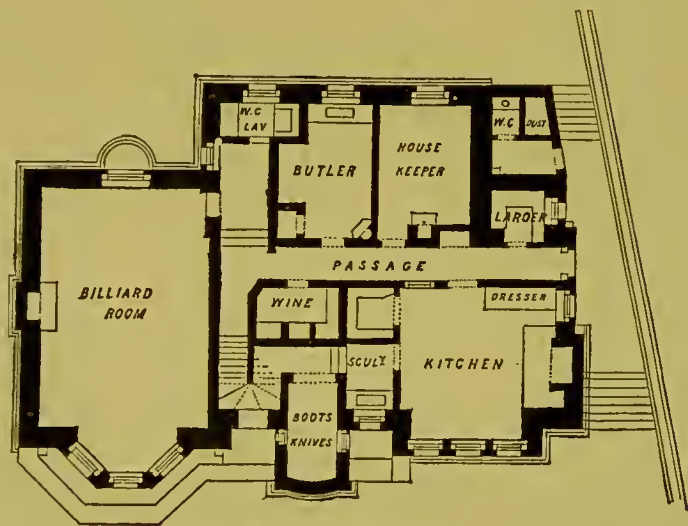


Fig. 140.—Basement Plan.

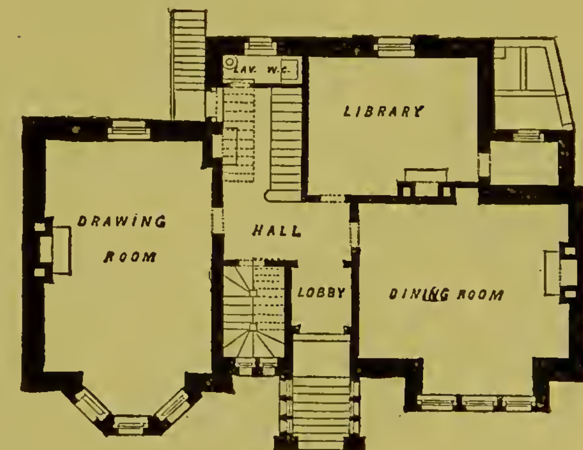


Fig. 141.—Ground Floor Plan.

Detached House in Fitzjohn's Avenue.

beneath the dining-room, and a serving-lift from the passage just outside the kitchen affords convenient means of supplying the dining-room, and removing plates and dishes, &c., therefrom. The space beneath the front entrance steps and porch is utilised as a knife and boot cleaning room, from which is an entrance to the coal-cellar (under back stairs).

At the rear are the butler's pantry, housekeeper's room, and larder, also a servants' water-closet, and a dust-bin, approached from the open yard at the side of the house. A wine-cellar which, though small, is of sufficient size to hold a good stock, is arranged in the centre of this storey. A wise economy of space is effected by not continuing the main staircase down to the basement, a smaller staircase being contrived at the side of the billiard-room in such a way as to land on the ground floor in close proximity to the principal entrance. From this landing one door goes into the outer hall, and one to the inner, so that the front door may be opened by the servant without passing through the inner hall.

Approaching the ground floor by means of the front entrance, access is gained through an intervening lobby to the hall. This lobby is useful for protecting the interior of the house from an in-rush of cold air, or gusts of wind when the front door is opened. On the right of the hall is the dining-room, 22 feet by 17 feet, with a spacious projecting window of three lights. On the left is the drawing-room, 25 feet 4 inches by 17 feet 9 inches, with a bay window in front, and a single-light window at the rear. Behind the dining-room is the library, 17 feet 6 inches by 15 feet, with a small recess opening out of one corner for a writing-table. Between the drawing-room and the library is the main staircase, 8 feet wide, giving access from the ground floor to the first floor, and a lavatory and water-closet are formed beneath the first landing. A fireplace is provided in the hall for warming it and the staircase; and by the side of the fireplace is a doorway to give access to the garden by means of a flight of steps. This doorway is in closer proximity to the water-closet than desirable, but apparently it cannot very well be otherwise arranged.

On the first-floor, and over the drawing-room, is a bed-room, dressing-room, and bath-room with water-closet; and over the dining-room and library are three more bed-rooms.

The provision of a fireplace in the bath-room is an excellent arrangement, though frequently omitted in houses of this class. One of its most valuable uses is to remove from the bed-rooms and nurseries the airing of linen. The recess, which on the ground-floor forms part of the library, is on this floor thrown into the bed-room over the dining-room, by which the convenience of that bed-room is greatly increased, as the recess, though small, could be used as a dressing-closet, or as space for a writing-table.

The approach to the upper floor is by means of the second staircase, which is continued up from the basement. On the landing between the first and second floors is the housemaid's closet, well lighted and ventilated, and not the mere dark corner it too frequently is. Above this closet is a tank for rain-water. This is an unusual provision in town houses, but as the cistern is of slate, and contains a filter, and the draw-off pipe is lined with tin, it is useful for providing soft water for shaving and toilet use, &c. In this top storey or second floor will be found two servants' bed-rooms, one 17 feet by 16 feet 6 inches, and one about 12 feet by

11 feet; also a box-room, a cistern-room, easily accessible, and a studio, 25 feet 6 inches by 18 feet, having windows at each end, and a skylight near one end.

The whole of the basement is concreted, has Jennings' stoneware damp-course, and a dry area. The roofs are close boarded and felted, the floors pugged, and the ventilating gas-tubes and outer cisterns protected with Baatsch's slag felt.

The whole of the drains are outside, and discharge into a ventilating-chamber to prevent the entrance of sewer-air; the soil-pipes are outside, and have extracting cowls; and the rain-water pipes and wastes deliver over drain-intercepters. A galvanised iron tank supplies the water-closets, while the drinking, cooking, and bath water is supplied from slate cisterns. Hot water is supplied to the bath, the lavatories, and the housemaid's scullery and butler's sinks.

The billiard-room, drawing-room, dining-room, and main bed-rooms, together with the library and studio, have Boyd's hygeastic grates, and are heated by asbestos and gas. The dining-room, drawing-room, and library are lighted with Faraday's ventilating gas lamps. The dining-room and billiard-room chimneys have flue-pipes secured to the sides of the flues, but leaving an open space round them; and in the dining-room, drawing-room, and billiard-room, hit-and-miss ventilators are fixed in the chimney-breasts just below the ceiling to carry off foul air; these ventilating flues communicate with the outer air by means of gratings below the chimney-caps, protected by galvanised iron hoppers.

The halls and passages of basement and ground floor are paved with Burke's marble mosaic; and the kitchen, scullery, larder, and main kitchen passage, as well as servants' water-closets, are lined with white enamelled bricks.

HOUSE AT MARINE PARADE, BRIGHTON.

Figs. 144 to 146 illustrate the adaptation from the designs of Mr. Robert W. Edis, F.S.A., F.R.I.B.A., of an old cement-fronted sea-side house to modern ideas of comfort and healthy conditions.

From the exposed position in which the house is placed, subjected to driving rains and spray from the sea during the winter months, and to the glare of the sun in the summer, both of which are intensified by local conditions, the most important points to be attended to were to secure as much as possible a minimum degree of variation in temperature, and immunity from damp.

The old house being fairly well built, it was not deemed advisable to pull it down altogether. The walls were, therefore, left standing; and in order to gain the desirable thickness, they were cased with thin red bricks and cut-flint work, all well bonded into the old work, and built in Portland cement. The upper floors were faced with ornamental weather tiling. These precautions have had the desired effect of rendering the house impervious to driving wet, and also capable of being kept warm in winter and cool in summer.

The old slated roof was removed, and a high-pitched roof, covered with plain tiles, substituted. This alteration was made, however, before the old roof was removed, so that the damage which is so frequently done to houses undergoing alterations of a like kind, by saturation with rain between the time of the removal of the old and the completion of the new roof, was obviated. The eaves are brought well out over the walls, and thus serve as an additional protection against rain and sun.

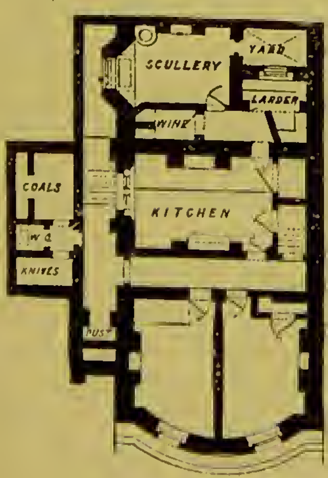


Fig. 144.—Basement Plan.

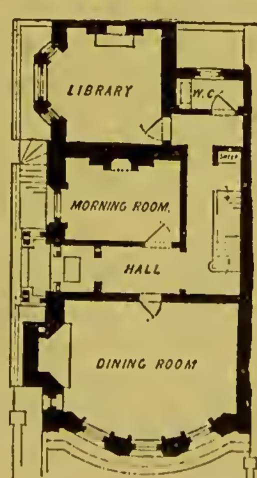


Fig. 145.—Ground Plan.

Fig. 146.—First Floor Plan.

— SCALE —

A Sea-side House—No. 70, Marine Parade, Brighton.

Marked and characteristic features in the front are the balconies and verandah, all executed in wood, and forming, as such features should, but seldom do, essential parts of the general design.

The two upper floors were entirely gutted, the third floor raised two feet, and a new attic storey added.

The basement was re-arranged, the two front rooms being made into butler's pantry and servants' hall. On the old yard at the back were erected scullery, larders, &c.; and above these, on the ground floor, a library; and on the upper floor, bed-rooms, bath-rooms, &c.

The hall was enlarged; the staircase was unaltered, except that "petticoat" balusters were substituted for the old straight wooden ones, in order to increase the somewhat confined space.

The whole system of drainage was re-arranged, and by a simple method the length of drain was reduced to a minimum, and the whole of the refuse of the house reaches the sewer by the shortest possible road. The drains are ventilated and disconnected in accordance with modern principles of sanitation.

Internally the house was fitted up with modern appliances, and artistic decorations and fittings (mantel-pieces, &c.), carried out from the designs of the architect.

The cost of the whole work was under £3,000.

HOUSE IN HAMPSTEAD HILL GARDENS.

Figs. 147 to 150 give the plans of a house, with studio, built for Thomas Collier, Esq., the well-known painter, from the designs of Messrs. Batterbury and Huxley.

Situated on the slope of the hill, advantage has been taken of the formation of the ground to arrange the lowest floor as a half-sunk basement in the front where the ground is highest, whilst at the back the rooms are nearly on the ground level.

The basement floor contains kitchen, scullery, larder, coal-cellar, beer-cellar, and wine-cellar, breakfast-room, and billiard-room. The tradesmen's entrance is on one side, and approached from the area on the same side are the servants' water-closet and the dust-bin. The arrangement of a lobby outside the kitchen and the larder, prevents the approach to the billiard-room, breakfast-room, and garden entrance (which separates the last two) from being overlooked from the kitchen. The billiard-room is a spacious room (24′.0″ × 20′.0″), lighted on three sides by broad windows reaching well up to the ceiling; the formation of a skylight, or lantern-light, was precluded by the fact that immediately over the billiard room is the floor of the studio. It is found, however, that the form of lighting adopted is quite as effective as a direct top light, while for many reasons it is very much more convenient and pleasant to the eye.

On the ground floor, the principal entrance is in the front, and is approached by a flight of steps. Passing through an outer lobby, access is obtained through an outer and smaller hall, in which a small niche, semicircular on plan, and fitted with shelves for decorative china, &c., forms a picturesque and pleasing feature, to the inner hall, off which the principal rooms are arranged. To the left of the inner hall are, at the front, the dining-room (17′.0″ × 20′.0″); and at the back, the drawing-

room (21′.0″ × 17′.0″); and the studio (24′.0″ × 20′.0″), a spacious and well-lighted room, additional height being obtained by taking it up partly through the first floor.

In the front part of the house, and to the right of the entrance, is a lavatory and cloak-room, which forms a vestibule to a water-closet. Adjoining these is a room which serves the double purpose of pantry and store-room.

Fig. 149.—First Floor Plan.

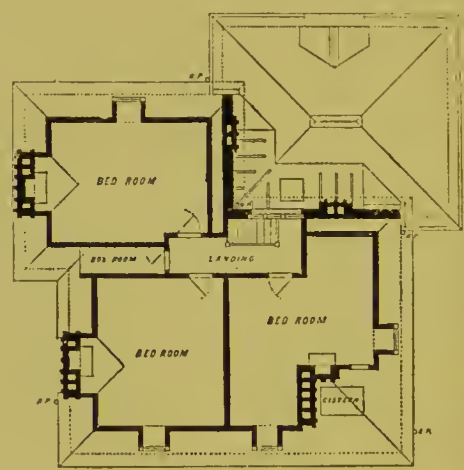


Fig. 150.—Upper Plan.

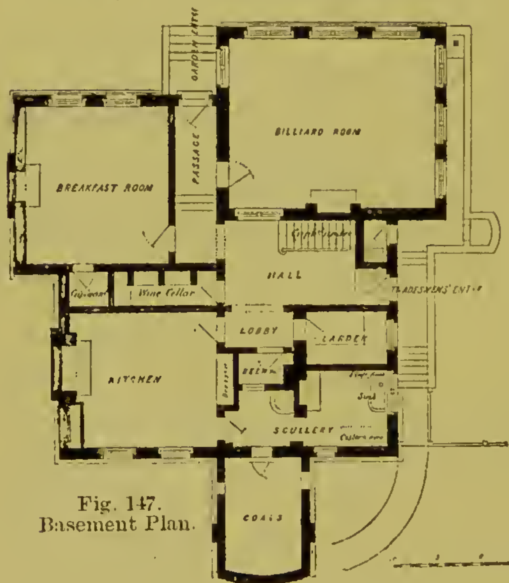


Fig. 147.
Basement Plan.

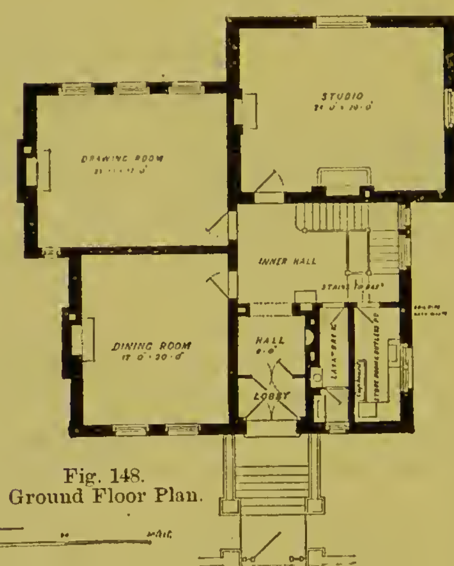


Fig. 148.
Ground Floor Plan.

House in Hampstead Hill Gardens.

The first floor contains four bed-rooms and a dressing-room, bath-room, and water-closet. The provision of a fire-place in the bath-room is a somewhat unusual but very excellent arrangement. There is no room over the studio, a fact which is accounted for by the arrangement for gaining height referred to above.

Three spacious rooms are obtained in the roof, each of which is duly provided with a fire-place. A small box-room is also provided at this level, and a staircase gives ready and convenient access to the roof.

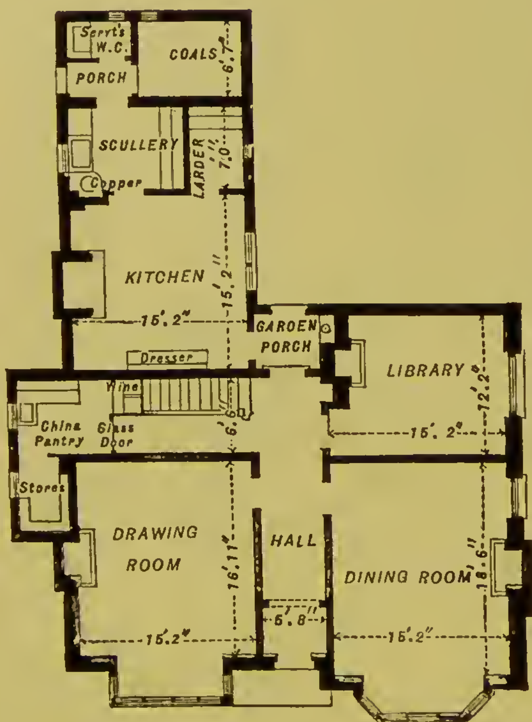


Fig. 151.—Ground Floor Plan.

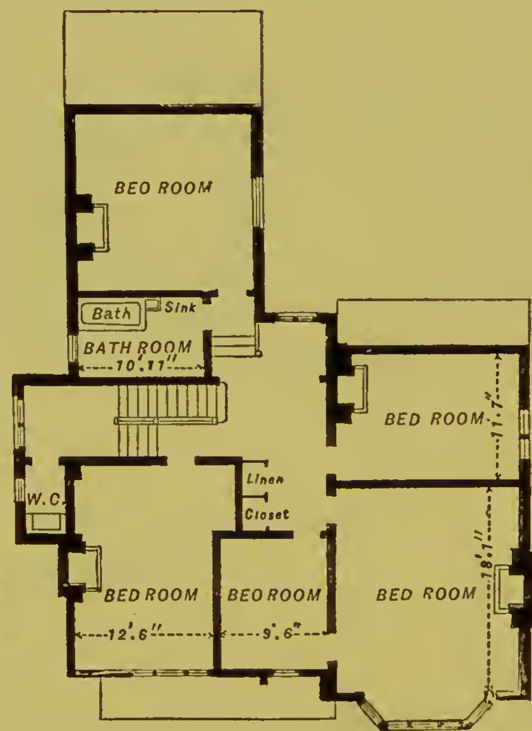


Fig. 152.—First Floor Plan.

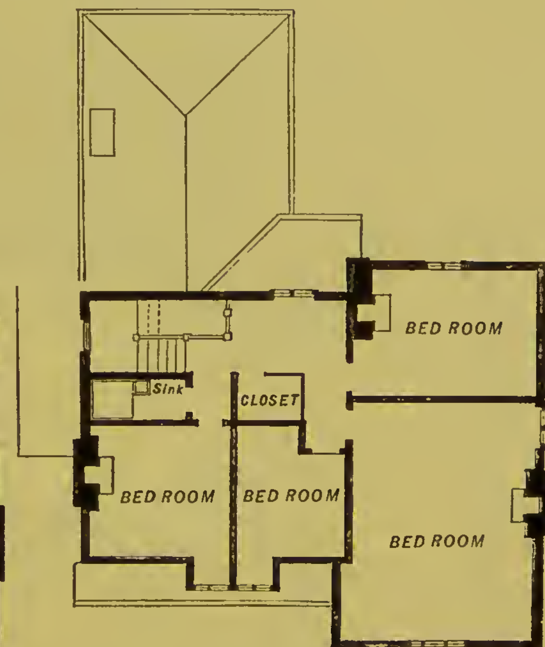
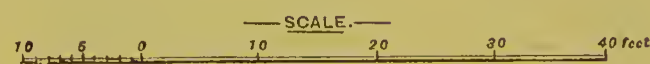


Fig. 153.—Second Floor Plan.



House at Ealing.

HOUSE AT EALING.

Figs. 151 to 153 are illustrations of a carefully planned detached house, designed by Mr. W. J. Green.

The entrance is in the centre and on the south side of the house. On either side of the entrance hall are the dining-room (15'.0" × 18'.4"), and the drawing-room (15'.0" × 16':9"), each with a bay window. Behind the dining-room, and lighted from the east, is the library (15'.0" × 12'.0"). Behind the drawing-room is the staircase, at the end of which are arranged a china pantry, with sink, &c., a store-room, and a small wine-cellar under the stairs. The staircase wall is continued across the hall, and so shuts off the kitchen offices. A glass door in this wall opens on to a small lobby, whence access is obtained to the garden and the kitchen. In this lobby, or "garden porch," is a lavatory basin fitted in to the recess formed by the library fire-place. The kitchen (15'.0" × 15'.0"), a convenient-sized room, is lighted from the east. Communicating therewith are—the larder, also lighted from the east, and the scullery, with sink, copper, &c. A porch to the side entrance divides the scullery from the servants' water-closet, and also gives access to the coal-cellar. Up-stairs there are, on the first floor, five bed-rooms, a bath-room, and a water-closet; and on the attic floor, four bed-rooms, a housemaid's closet and cistern-room, and a large closet.

While the plan presents no very marked features of originality, there is evidence of a careful study of detail which will well repay examination. Specially to be noted is the way in which the fire-places on the ground floor are worked in, with, in one case, the store closet, in another, a recess for lavatory basin. The position of the water-closet on the first floor could not be improved upon, and the provision of a housemaid's sink on each bed-room floor is a most useful arrangement.

HOUSES AT BALHAM.

An example of a semi-detached house, erected from the designs of Mr. Henry Hall, the rental value of which would be about £70 to £80, is given in Figs. 154 to 157.

The basement, which is about 3'.6" out of the ground, contains breakfast-room, with a store closet, kitchen, scullery, larder, wine-cellar, and coal-cellar. Approached by a lobby is the servants' water-closet, while in the open yard at the side is the dust-bin. An additional closet is also provided under the stairs. The size and disposition of the rooms is governed by the floor above. It is difficult to see how the space could have been more advantageously arranged; the only point that seems open to criticism being the position of the larder window with reference to the dust-bin. It is within the limits of possibility that particles of decomposing matter might be blown from the dust-bin into the larder. This is perhaps hypercritical, and, moreover, decomposing matter has no right to be in the dust-bin. The ground floor, approached by a flight of steps and a porch, contains lobby (with inner door), entrance hall, dining-room (13'.6" × 16'.0", with bay window), drawing-room (20'.0" × 14'.0"), garden entrance, and water-closet. The stairs to the basement are screened off by a door at the top. The bay window in the dining-room is a useful feature, giving space for a writing or work table in addition to the dinner table. In houses of this character, where the dining-room is used as the general sitting-room for the greater part of the day

(except where the breakfast-room in the basement is used for the purpose), adjuncts of this kind materially increase the comfort and usefulness of the room, without adding greatly to the cost.

The first floor contains one bed-room 12′.0″ × 16′.0″, one 12′.0″ × 14′.0″, and one

Fig. 156.—First Floor Plan.

Fig. 157. Second Floor Plan.

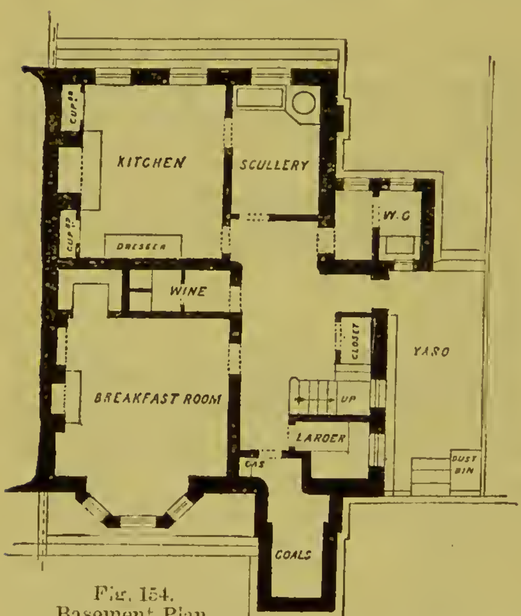


Fig. 154.
Basement Plan.

Fig. 155.
Ground Plan.

— SCALE —

Semi-detached Houses at Balham.

11′.6″ × 9′.0″; also a dressing-room, a linen closet, and a bath-room and water-closet combined.

The second floor contains two good bed-rooms—one 13′.6″ × 16′.0″, the other 13′.6″ × 14′.0″, and another smaller one. The corner of the sloping roof is utilised as a box-room. A door of communication between the front and back bed-rooms on this floor might easily be made if these rooms were required as nurseries.

The staircase and the water-closets are both well arranged. The former is

planned in three flights to each floor, and without the aid of any winding steps in the whole staircase. The position of the water-closets, separated from the main house, and placed as they should be one over the other, is admirably contrived. The arrangement for ventilating the closets with opposite windows, by which a through current of air is obtainable, is likewise especially good. It may be contended that a water-closet in a bath-room is an arrangement to be avoided, but it is so commonly adopted as to leave little doubt about its being free from serious objection. There are clearly many advantages in having a water-closet in a bath-room; the plumbing work is more concentrated, and the convenience of such an arrangement cannot be questioned. Any objection on the score of cleanliness would rest on the abuse of the arrangement rather than on its proper use.

Again, the fact that a perambulator may have to be stowed away somewhere has evidently not been lost sight of, ample space being provided either in the lobby to the front door, or in the recess formed by the basement stairs.

These apparently minor points are referred to because they are just those important details which so rarely receive the attention they demand from the designers of the ordinary speculating builder's house; and only those people who have had the advantage of living in a well-designed house can point out the vast increase of comfort that might be afforded by more careful study of these details.

The soil upon which these houses were built was clay, the clay which was dug out for the foundations being burnt and ground in a mortar-mill with lime for mortar, and also used for paths. The materials used for the walls were stock bricks, with red brick facings and Bath stone dressings. The whole of the walls rest on concrete foundations about 2'.6" deep, and a stratum of concrete six inches thick was laid under the whole area of the house. A damp-proof course of Seyssel asphalte was laid over the walls at the ground level, and open areas were formed at front and back, and dry areas at the sides.

The cost of each pair, exclusive of fencing and front boundary-wall, was about £2,475; the fencing and front boundary-wall amounting to about £110 additional.

HOUSE AT WOKING.

This is a small country house, erected from the designs of Mr. Henry Hall (Figs. 158 and 159). It is built on the top of a hill, and considerable additional expense was thereby incurred in excavation and in forming retaining walls.

The house had to be so planned that the sitting-rooms should command extensive and beautiful views, and this rendered it necessary that the drawing-room and the dining-room should face the south.

The entrance is on the east; an enclosed porch, with a seat on either side, gives access to the front door. Immediately within the latter is a vestibule, from which access is obtained on the left hand to the lavatory and cloak-room, and an earth closet. In this lavatory is an urinal basin, cased in with woodwork. Entering the hall on the right is the dining-room (17'.0" × 14'.0"), with a bay window towards the east. Beyond this is the drawing room (13'.6" × 16'.0"), also with a bay window, but facing southwards. Next to the drawing-room is the library (13'.0" × 11'.6"), with a

French window opening into the garden. On the left of the hall a small wine store is provided, beyond which is the door of communication with the kitchen offices. These last, on a slightly lower level, consist of kitchen (14'.6" × 11'.6"), with a large store closet, scullery (with sinks and copper), and larder. A lobby between the kitchen and the two last-named offices gives access to the kitchen yard, at one extremity of which will be found the servants' earth closet; whilst at the other a shed forms coal-store and pump-room. The well is shown just outside the pump-room, and is sixty feet deep. In the angle of the yard is the dust-bin.

A conveniently-arranged flight of stairs, devoid of winding steps, gives access to the bed-room floor. The bed-rooms are four in number, and by the diminished thickness of the walls on this storey, are slightly larger than the rooms beneath them. Over the vestibule and wine-store, and the passage to the lavatory, is a dressing-

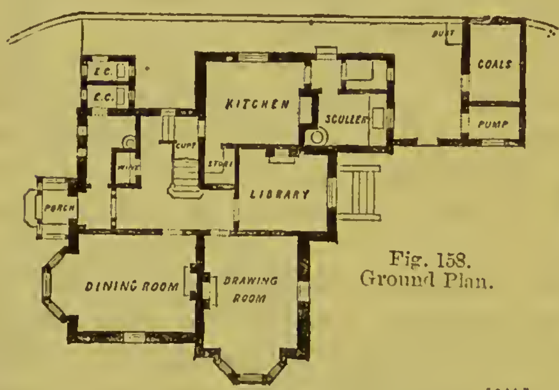


Fig. 158.
Ground Plan.

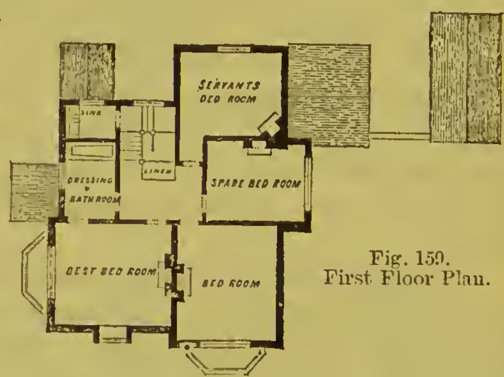


Fig. 159.
First Floor Plan.

DETACHED HOUSE AT WOKING.

room, in which is a bath with hot and cold water laid on. At the head of the staircase, a specially contrived linen-store is arranged. The water-closet and slop-sink are entered from the second landing above the ground floor.

The walls on the ground floor are all faced with red bricks, the upper part being built of local bricks nine inches thick, and faced with weather-tiling. The roof is covered with plain tiles. The drainage is taken to a cess-pool about 100 yards distant, at the bottom of the hill.

The cost of the house, exclusive of approaches, retaining walls, excavation of bank, and the formation of well, was £1,785. The cost of the well was £123.

A "BUNGALOW" AT WESTCLIFF, BIRCHINGTON-ON-SEA, THANET.

Fig. 160 is the plan of a house of a somewhat unique character, erected from the designs of Mr. John Taylor. It is intended as a summer residence for a family, or as a private sanatorium, the situation being peculiarly favourable for such a purpose from the invigorating quality of the air.

The idea in view was to produce an arrangement that should be capable of affording the greatest comfort with the least amount of household labour, and at as small a cost as possible, consistently with sound work. Following out this idea,

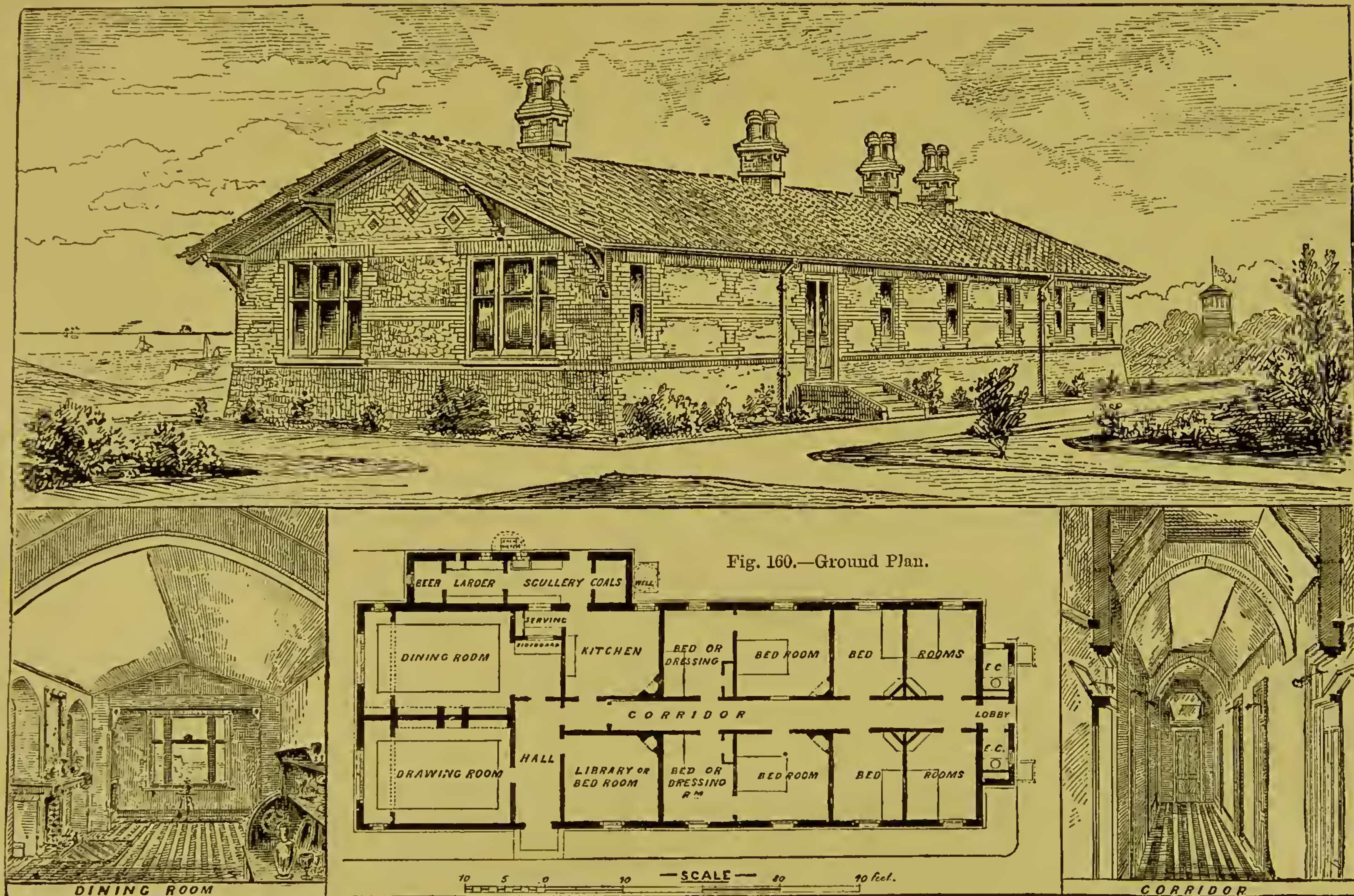


Fig. 160.—Ground Plan.

"Bungalow" at Birchington-on-Sea.

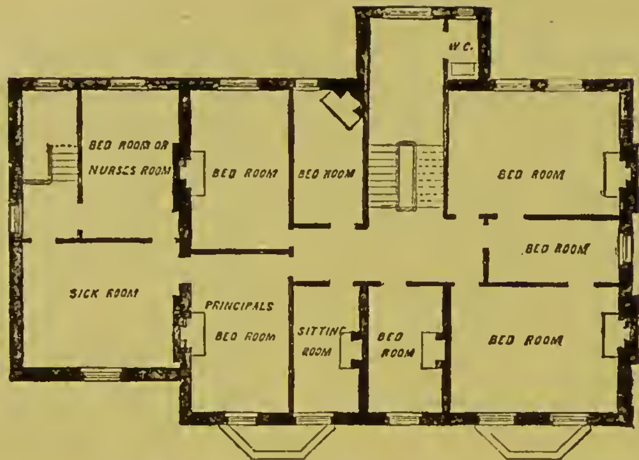


Fig. 163.—First Floor Plan.

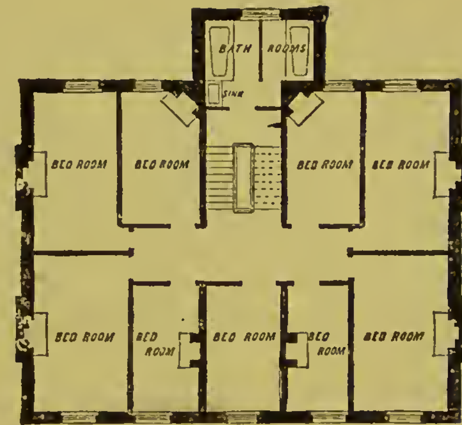


Fig. 164.—Second Floor Plan.

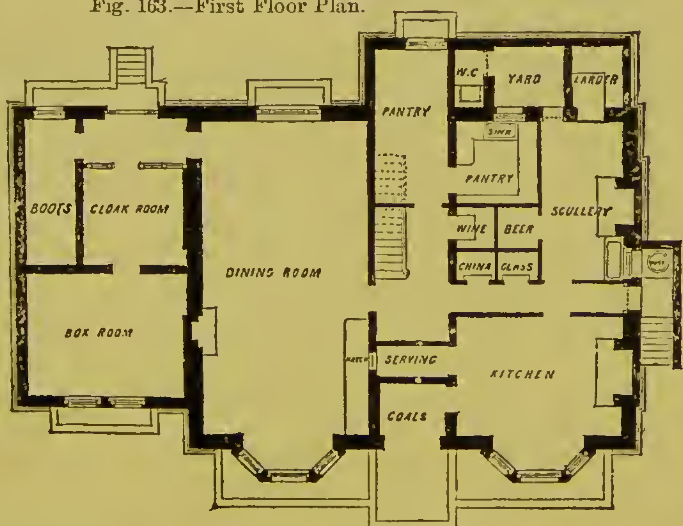


Fig. 161.—Basement Plan.

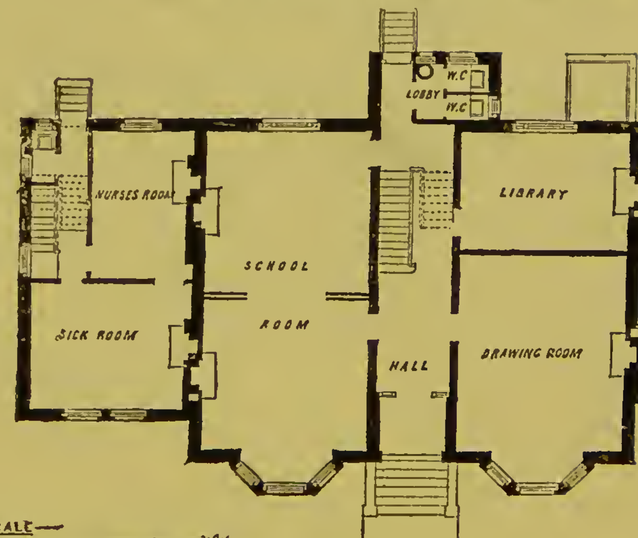


Fig. 162.—Ground Plan.

—SCALE—

House for School, at Brighton.

the whole of the house is planned on the ground floor, and is covered by one continuous roof, which is of the simplest possible form and construction.

The principal entrance is at the side, there being in addition a tradesmen's entrance close to the kitchen offices, and a garden entrance at the end of the bed-room corridor. Occupying the whole of one end of the house are the dining and drawing-rooms, the former with a deep recess for the sideboard, in the centre of which is a serving hatch, communicating with a serving lobby. This latter has direct communication with the kitchen, of which it is in fact a recess, and also by means of a window with the scullery. In immediate connection with the kitchen are the scullery, larder, beer-cellar, and coal-store.

Opposite the drawing-room is a smaller room, which is intended to be used either as library or bed-room.

A central corridor gives access to the bed-rooms, eight in number, eaca of which is provided with a fire-place.

The closets are Moule's earth closets, the tanks or receptacles to which are removed and emptied from the outside. The slop drainage is conveyed to a cess-pool sunk in the chalk. The water supply is derived from a well sixty feet deep, and from a tank in which is stored the whole of the rain-water from the surface of the roof.

The main difficulty to be overcome in the construction of the house was the penetrating nature both of the driving rains and the sea-spray. All ordinary methods failing, Mr. Taylor devised a mode of forming an upright damp-proof course, which has proved perfectly successful. It consists of vertical slabs of slate built up the centre of the wall, the bond being maintained by means of iron ties, which serve also as chairs in which to rest the slate slabs.

HOUSE AT BRIGHTON.

Figs. 161 to 164 illustrate an excellent arrangement of a school, designed by Mr. H. J. Lanchester, for a limited number of young ladies, in Wilbury Road, West Brighton, so as to have all the appearance of a private house. As will be seen from the plan, the dormitories are arranged so that many of the pupils have a bed-room to themselves, while a few of the rooms are arranged to be occupied by two sisters; and thus a total of from twenty-seven to thirty pupils can be accommodated.

The lowest storey is a half-sunk basement containing, besides the usual domestic offices, an excellent refectory and play-room 35 × 18 feet. The school-room, immediately over the refectory, is a good room, with windows in its opposite end walls, and affords the ample amount of twenty feet of floor-space to each pupil when they are all in the room at one time. It is 11 feet 9 inches high, and is warmed by two ventilating grates. The water-closets, which are fitted with the "wash-out" apparatus, are arranged in a projection from the rear of the staircase; and in the upper part of this projection are the baths, which are fitted with shower-baths.

An important feature in this school is the annexe at one side of the house. This wing, which is intended as a kind of infirmary, with the exception of double doors direct from the principal's own bed-room, is accessible only by an external

approach from the garden. It is only two storeys high above ground, while the house itself is four storeys in height above the basement. In this annexe can be isolated any pupil immediately any disorder is detected, and thus the health of the other pupils is protected from all danger of taking even the most trivial complaint that might be communicated from one to another. The value of such an arrangement has over and over again been proved, and while the isolation is complete, the youthful patient is not deprived of the care and attention of the principal herself. The basement of this annexe having no communication whatever with the upper storeys, affords convenient space for the children's garden clothes, boots, &c. ; and a front room is also here set apart as a box-room for the pupils' luggage, which is brought in at one of the windows direct from the road, and thus all difficulty of taking the boxes up-stairs is got rid of.

The entire building is generally of a plain and substantial character ; the external walls are faced with a waterproof brick that has been patented by the architect, which tends to protect the house from the driving rains and changes in external temperature.

CHAPTER XXI.

PARSONAGES.

Peculiar Circumstances and Requirements of Parsonages—Rules and Instructions of the Ecclesiastical Commissioners—Examples at Forest Row and Kirdford.

In discussing the arrangements of an ordinary country parsonage it is necessary to bear in mind the special circumstances which distinguish this class of house from other houses of similar dimensions.

The principal distinctive feature about a parsonage is, that it is inhabited by a succession of owners whose circumstances may be, and frequently are, widely different. While the amount of the income of the living remains fixed within certain limits, the actual income possessed by any one occupant may, on the one hand, be restricted to that amount, or, on the other hand, it may be considerably greater by reason of private means possessed by the incumbent. The tenure also of a parsonage is peculiar. It, together with the glebe, belongs to the incumbent absolutely so long as his incumbency lasts. While, however, the incumbent's tenure is freehold so long as it endures, he (or his executor), is liable to his successor to deliver up the building at the determination of his incumbency in a perfect state, without allowance even for wear and tear. The effect of this system makes the incumbent at once both tenant and landlord. The necessity, therefore, for building parsonages in the most substantial manner possible is obvious. Another no less important consideration, involved by the peculiar circumstances of the holding, is that the size and character of the house must always bear a due proportion to the value of the living. In building or altering a parsonage, regard must always be had, not to the special circumstances or requirements of any one particular incumbent, but to the reasonable requirements of an incumbent solely dependent on the income belonging to the living. It will readily be understood that if this rule were not strictly observed, a rich incumbent of a poor benefice might burden his successors with a house costly in maintenance and repairs, and quite beyond their means to keep up. Again, an unmarried incumbent might build a house in every way suitable to his own requirements as a bachelor, but utterly inadequate for the accommodation of a married parson with a young and numerous family.

The first point, therefore, to ascertain in designing a parsonage-house is the value of the living. This preliminary being settled, the important points to be kept in view are, first, to fit the accommodation to the income derivable from the living, and secondly, to adopt as durable a mode of construction as possible in every particular, and thus avoid to the utmost all necessity for periodical expenditure in repairs.

It may, however, be advisable, under certain circumstances, to build a parsonage of somewhat small dimensions, and to arrange it with a view to future enlargement. This can readily be accomplished by inserting brest-summers or lintels for future bay windows, by making the roof large enough to admit the addition of attics, and by other arrangements to allow of subsequent extensions. When the future

formation of attics is contemplated, the ceiling-joists of the upper floor will necessarily have to be of sufficient strength to serve as floor-joists when the attics are formed.

The "Rules and Instructions respecting Parsonage-Houses," issued by the Ecclesiastical Commissioners, are so practical and to the point, that no apology is needed for quoting somewhat largely from them. It will be found, moreover, that although they are issued with special reference to, they by no means apply solely to parsonage-houses; they are equally valuable in most instances when applied to any kind of house, and especially to country houses of a small or moderate size.

Referring to the amount of accommodation to be provided, the Commissioners recommend that there should be "two sitting-rooms, not less than 16 feet by 14 feet; a study about 14 feet by 12 feet; a kitchen, and a scullery, and not fewer than five bed-rooms, each bed-room having a fireplace. There should also be a pantry or china-closet, larder, water-closet, wine and beer cellar, coal-house, dust-bin, &c."

The above dimensions will, of course, have to be varied as circumstances suggest; it will, however, in practice, be found advisable, at least in country parsonages where no special parish-room is provided, to make the dining-room somewhat larger than the above dimensions, in order that it may be more conveniently available for the meetings of clergy, parishioners, and others, which so frequently occur in a country parsonage.

The other sitting-room will, of course, be the drawing-room, and, as such, calls for no special remark; it should, however, be borne in mind that both these rooms must have a cheerful and sunny aspect.

The study is a room of special importance in a parsonage, and its position and arrangement demand no little attention on the part of the architect. Being the parson's workroom, it must be so placed that its occupant may be undisturbed by the noise of the household. Being also the room where parish business is transacted, and where interviews between the clergyman and his parishioners ordinarily take place, it must be easily accessible both by the front and back doors. As a rule, the size given by the Commissioners will be found to be ample; occasionally, however, space has to be found for a large library belonging to the parish, and the dimensions of the study must be regulated accordingly.

The servants' offices will not differ materially from those of any ordinary house of a similar size. It should, however, be remembered in planning the back entrance that the callers at a parsonage are somewhat numerous; and while some provision in the shape of a porch or lobby may conveniently be made for the accommodation of people waiting, the view of the kitchen offices should be effectually screened from the back door. Where there is a parish-room attached to a parsonage, the same lobby may conveniently serve both for it and for the back door. In addition to the servants' offices mentioned in the "Rules," a dairy will, in most country parsonages, have to be provided; also a wood-house, and space to store dry earth for winter consumption in the earth-closets, when such closets are adopted. To the five bed-rooms recommended by the Commissioners as a minimum provision, a dressing-room, large enough to serve as a bed-room if required, may be added with advantage; and it should also be held in view, in arranging the bed-rooms, that it is within the limits of possibility that two of them may be required for use as nurseries.

A very convenient adjunct not mentioned by the Commissioners is a back staircase, or at least a portion of one—that is, from the ground-level to the first landing. Where any of the sitting-rooms are on the first floor, the back staircase ought to go the whole height of the storey.

The parish-room forms a most useful adjunct to a country parsonage. An example of such a room will be seen in the plan of Forest Row Vicarage (page 246). "This does not," as Mr. Lacy W. Ridge remarks,* "mean a small public hall, such as that attached to the church of Whitechapel, or those which some London clergymen have provided; but a rough room, suitable for night-schools, choir-practices, and similar meetings, to which people will come in their working clothes—a place where mothers' meetings may be held, the parish lending-library kept, soup distributed, blankets served out, and the hundred and one things done of which a rural parsonage is the centre." The proper place for the parish-room will be close to the back entrance, and within easy access of the study, in connection with which it may usefully serve as a waiting-room.

In all arrangements, whether of planning, or details of construction and fittings, the main point of economy of labour must never be lost sight of; and while providing windows and doors in ample numbers, and in the most convenient positions, regard must always be had to such matters as curtains, glass, and likewise to the number of shutters, bolts, &c., to be moved twice daily. All needless labour, both in the internal economy of the house and in its maintenance, should most carefully be guarded against; and upon the latter point the Commissioners have a rule of very great value :—"The law of dilapidations affecting ecclesiastical houses of residence renders it essential that particular attention should be paid to stability; and with a view to economy, and the avoidance of dilapidation risks, the Commissioners strongly recommend that ornamental features should, as much as possible, be avoided."

The following are the rules laid down by the Commissioners for the construction of parsonages :—

"All external walls to be of hard, well-burnt brick, or stone, but without any coating of cement or rough cast; if of brick, to be not less than fourteen inches; if of stone, not less than twenty inches thick; internal walls, brick (nine inches), stone, rubble, or random course of proportionate thickness.

"In exposed positions the thickness of external walls on the weather sides must be increased according to local requirements. Such walls may be built hollow, great care being taken to bond them properly, especially under the wall-plates; and special provision must be made for protection of window and door openings by a weather-proof course built in over each. The bonding-ties in hollow walls must be impervious to damp.

"Battening may be used when the nature of the materials of which walls are built requires it, for avoidance of internal dampness; but it is worse than useless when applied to walls not first made water-proof.

"In all walls, external or internal, a course of slate, laid in cement, asphalte, or some other impervious material, must be inserted above the ground-line through their entire thickness, to prevent the damp rising. Gratings to be provided for

* Paper on Parsonages, read before the Archæological Association, January, 1881.

ventilation under floors, to be so placed as to ensure a perfect current of air below the joists.

"Stone or brick to be used for all chimney-stacks, copings, external cornices, ornaments, &c., and five-pound lead for all flashings, &c. Cement or zinc for any of the above purposes will not be allowed.

"Basement stairs to be of stone, slate, or suitable bricks.

"All hearths to be laid on brick trimmer arches or rough stone slabs.

"Drains to be constructed with glazed stoneware pipes, with socket-joints not less than six inches in diameter for foul drainage, or four inches for rain-water, and to be carefully trapped where necessary. Overflow drains from rain-water tanks must not be connected with any sewage or foul water drain.

"No main partitions to be constructed of wood, either in the basement or ground floor.

"Baltic wood or oak to be used in the roofs, joists, and partitions, and all other constructive parts of the house; also for all external joiners' work and floors.

"The sills of all wood window-frames to be of oak.

"No joists or rafters to exceed one foot apart in the clear.

"The scantlings of joists for floors to be not less than is indicated by the following table:—

Length of bearing in feet.	Breadth 2¼. Depth in inches.	Length of bearing in feet.	Breadth 2¼. Depth in inches.	Length of bearing in feet.	Breadth 2¼. Depth in inches.
5	5	10	8	15	10½
6	5½	11	8½	16	11
7	6½	12	9	17	12
8	7	13	9½	18	12 × 3
9	7½	14	10		

"When the length of bearing exceeds eight feet, the joists must be strutted by one row, and when it exceeds twelve feet, by two rows of struts.

"As the construction of the roof will depend upon the design of the house, no table of scantlings is given, but the timbers must be strong, and of a substance proportionate to the foregoing table. The unsupported bearing of purlins must not exceed ten feet. Convenient means of access to the interior of roofs and to all lead gutters to be provided.

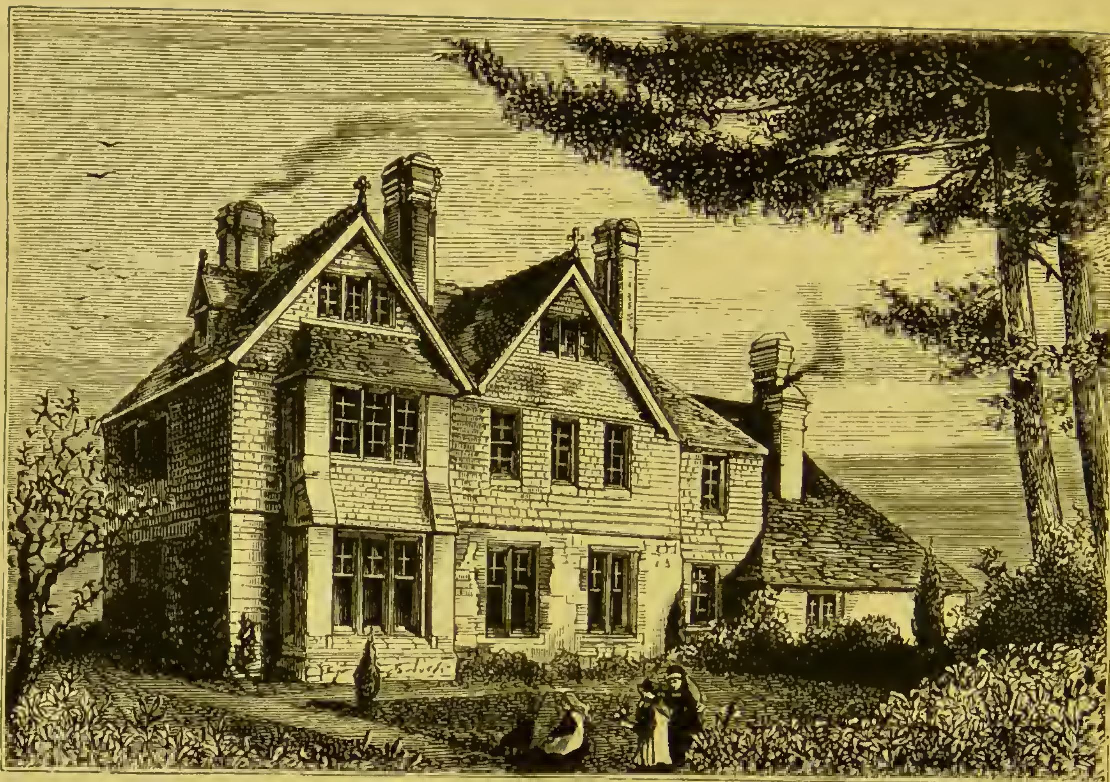
"Roof covering to be of slate, stone, or tiles; all slate to be fastened with copper nails. The interior of roof-covering to be pointed.

"Cisterns, when not of stone or slate, to be lined with lead; the sides to be of six pounds, and the bottom of eight pounds to the foot superficial, at the least.

"Middle roof and parapet gutters to be of seven-pound lead. Eaves, gutters, and rain-water pipes to be of cast iron.

"Wood and iron work to have four coats of paint throughout; but, if preferred, internal woodwork may be varnished only, or stained and varnished."

One or two points with reference to the foregoing most excellent rules may be noticed. First, as regards walls, the rules seem to preclude the possibility of building external brick walls of a less thickness than fourteen inches. In practice, however, it is quite permissible, and, indeed, often desirable, both for appearance



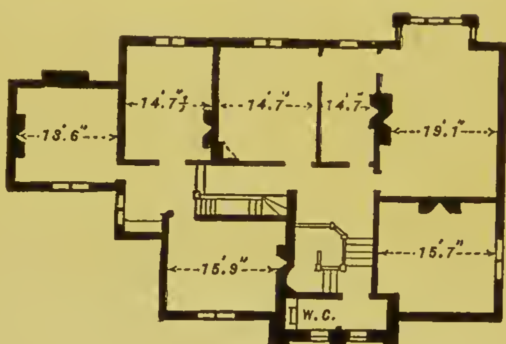


Fig. 165.—First Floor Plan.

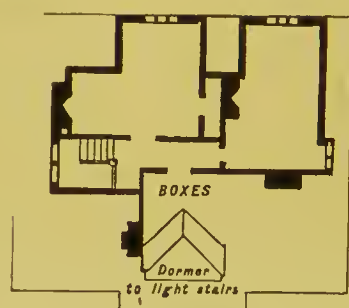


Fig. 166.—Attic Plan.

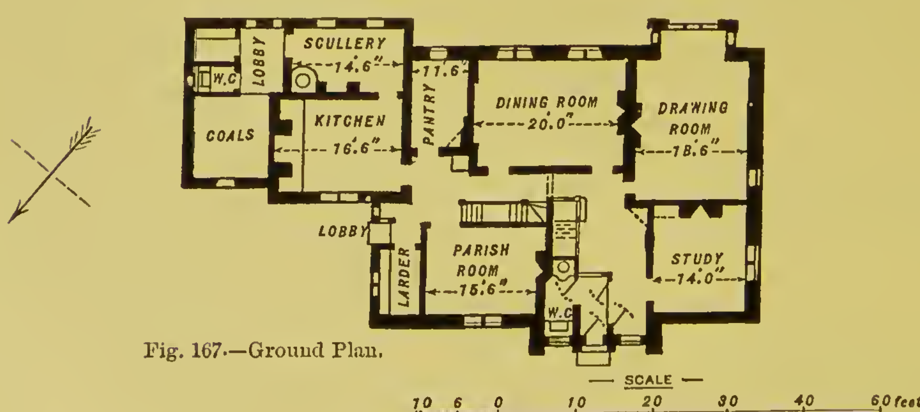


Fig. 167.—Ground Plan.

Forest Row Vicarage.

and dryness, to build the walls of the upper storeys of 9-inch brickwork, faced with weather-tiling. To economise materials, the bricks, if fairly square, may be laid on edge, Flemish bond, but with the intermediate brick omitted (*see* Fig. 15). The tiles can be nailed to the joint of the brickwork. When this method is adopted, and the lowest courses of weather-tiles project sufficiently, the three courses of brickwork below the wall-plate can be built solid; this will give a solid bearing for the wall-plate and joist, and the weather-tiling will keep the work dry.

Battening is permitted by the rules; it would, however, have been better to have prohibited it altogether. With a properly-constructed hollow wall there

KIRDFORD VICARAGE.

is really no necessity for its use, and it is most objectionable from many causes, amongst the most prominent being, that the space between the wall and the boarding or canvas is an inevitable harbour for vermin, and that in re-papering the canvas of a battened room the temptation to leave the old paper unremoved is often too great to be resisted.

As practical illustrations of the foregoing remarks, the plans of two Sussex parsonages are given: one at Forest Row being rather larger, the other rather smaller than the average.

Forest Row Vicarage, near East Grinstead (erected from the designs of Mr. Lacy W. Ridge, F.R.I.B.A., Diocesan Surveyor for Chichester), is a specimen of a moderate-sized parsonage, with a parish-room attached.

The entrance-front faces north-west, whilst the aspect of the sitting-rooms is south-east and south-west.

The front door opens into a lobby, off which is a water-closet and lavatory, and thence into a hall. On the right is the study, 14′ 0″ × 12′ 6″—the size recommended

by the Ecclesiastical Commissioners. The hall is warmed by a stove in the angle formed by the projection of the drawing-room.

Immediately behind the study is the drawing-room, 18′ 6″ × 15′ 0″, with a projecting window, facing south-east. Adjoining this again is the dining-room 20′ 0″ × 14′ 0″, having the same aspect, and furnished with two doors, one opening into the hall, the other, designed as a serving-door, into the kitchen passage.

The parish-room, 15′ 6″ × 12′ 0″, is arranged close to the side entrance, but not so as in any way to mar the privacy of the servants' quarters.

The larder, pantry, kitchen, and scullery are all grouped together in a convenient manner; and the cleaning-room (for knives, boots, &c.) and the servants' earth-closet are approached from the scullery by a small intervening lobby, which serves at once the purposes of privacy and disconnection.

A back staircase leads from the kitchen passage to the bed-rooms on the first floor, and is continued to the attics.

Of bed-rooms there are, on the first floor, six, with a dressing-room in addition; and on the upper floor, two, with space in the roof to serve as box-room.

The construction of the house is simple, but effective. Rag-stone, with red brick facings to the windows, on the ground floor; 9-inch brickwork, faced with weather-tiling, to the upper floors; and the roofs covered with plain tiles, with ornamental ridges and finials of the same material, complete the list of materials so far as the exterior is concerned.

Kirdford Vicarage, in Sussex, by the same architect, is a somewhat smaller house, and has no parish-room attached to it. Being, therefore, likely to be of more general service as an ordinary detached house, as well as for its own special design, the plans are given on a larger scale. The arrangements are somewhat similar to those of the Forest Row house, but the construction is simpler in treatment, the ground storey being enclosed with hollow brick walls instead of stone.*

* For much valuable information on the subject of Parsonages we are indebted to Mr. Lacy W. Ridge, Diocesan Surveyor for Chichester.

Fig. 168.—Cellar Plan.

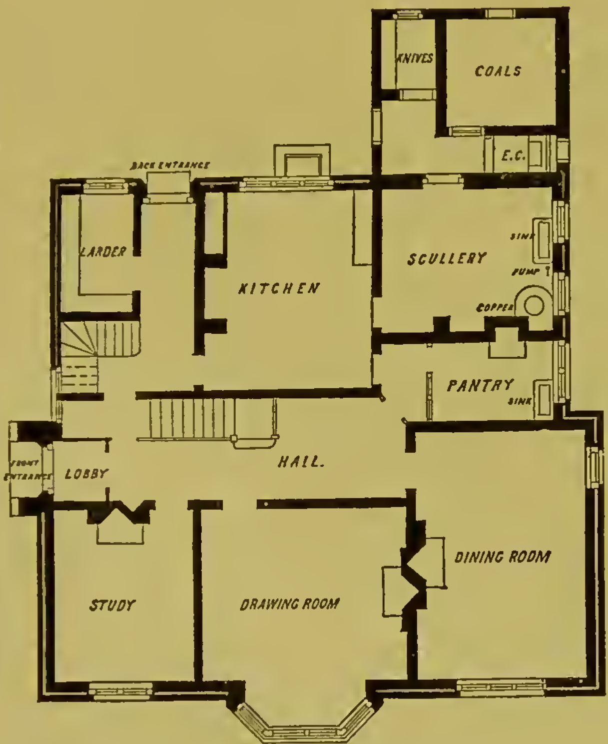


Fig. 169.—Ground Floor Plan.

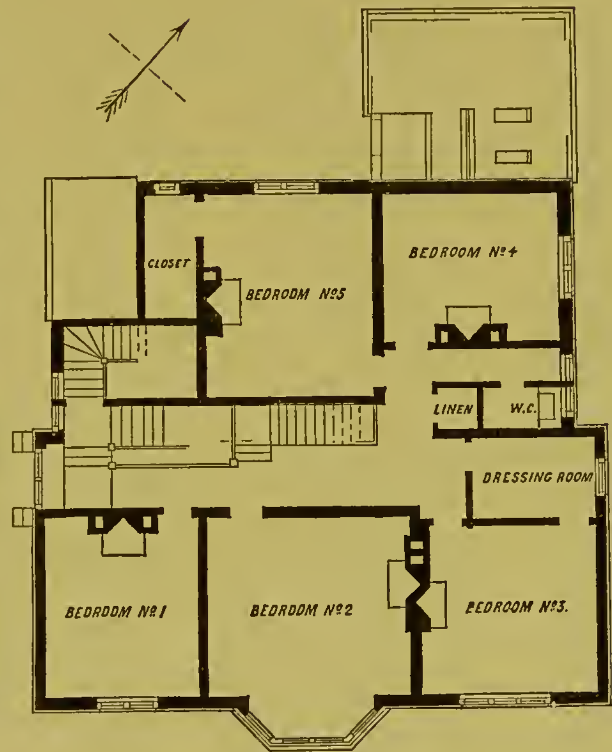
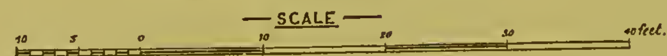


Fig. 170.—First Floor Plan.



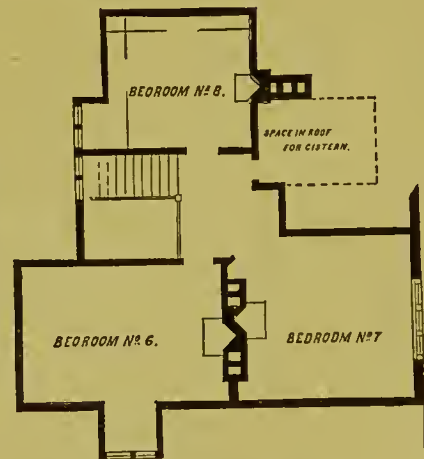


Fig. 171.—Attic Plan.

KIRDFORD VICARAGE, SUSSEX.

CHAPTER XXII.

LARGE HOUSES AND MANSIONS.

Residence of Sir Henry Peek, in Devonshire—Example of an old House re-modelled.

Houses of this kind are almost invariably, as a rule, designed and superintended by the best architectural skill of the day, the design being suited to the special circumstances and requirements. Accordingly only one example of a first-class modern country residence, designed according to the best modern methods, is given ; and as in some degree a contrast, but with useful practical lessons of its own, portions of the plans of an imposing town residence are also given, built in any but a sanitary manner, indicating how the evils thus caused were as far as possible mitigated.

ROUSDON.

Rousdon, Devonshire, is a house now approaching completion for Sir Henry Peek, Bart, M.P., from the designs of Messrs. Ernest George and Peto. It is selected for illustration as being an example of a large and very complete modern country mansion. Its completeness, indeed, may be said to be unique, for the boundaries of the estate itself are exactly co-terminous with the parish of Rousdon, the church having been rebuilt by Sir Henry Peek, and serving alike for parish church and private chapel.

The house is situate at the south-east corner of Devonshire, about three miles from the interesting old town of Lyme Regis, Dorset. It is on the top of a cliff about 400 feet above the sea-level, the grounds beneath comprising a beautiful bit of undercliff, by a pony drive through which access is gained to the beach.

The house is a long, low, and many-gabled structure of great picturesqueness, and designed specially with a view to stand the stress of wind from the sea. The style is late Tudor treated with freedom and originality. The main block is rectangular, with the rooms ranged round a central courtyard 42 feet square. In the middle of this court is an ancient well, over which is a marble curb and a cover of wrought copper-work. A wheel is arranged for lowering a man to the pumping-gear, which is worked by steam.

The principal rooms are ranged along the south side of the house, towards the sea. On this and the east front a broad terrace walk is constructed, an arrangement rendered possible by the fall of the ground from north to south.

A striking feature on this front is the group of three wide and lofty bay windows running up through three storeys.

The approach is from the north side through a square enclosed courtyard. The entrance-doors are sheltered by a carriage-porch enclosed with stone piers and arches, which carry a gabled superstructure of half-timber work. The timber used here is teak, and the panels are filled with decorative parget-work.

Entering at the principal door, access is gained to the great hall, 66 feet long by 26 feet wide. At the end nearest the entrance is a minstrels' gallery, the part below the gallery being screened off to form an ante-hall.

The hall has an open timber roof of oak, carried on carved stone corbels. The walls up to the height of the window-sills are panelled with wainscot, above which they are lined with dressed Beer stone. The six windows have each twelve lights filled with painted glass, the subjects being incidents connected with local history, which is singularly rich in stirring events. On one side of the hall is the ingle-nook, with its oak settles, and its hooded chimney reaching up to the roof.

The hall abuts on one side of the courtyard, on the other three sides being corridors lighted by mullioned windows from the court. These corridors give access to the reception-rooms.

At one end of the hall is the tower, which is occupied by Sir Henry Peek's own rooms. These are, on the ground floor the business or justice-room provided with its own small porch for access from the outside; in the basement approached by a staircase from the business-room is a strong-room, provided with means of warming and ventilation. A turret staircase leads from the ground floor to Sir Henry's dressing-room; above this to a room for documents, to the museum, and finally to the Belvedere. This last forms the uppermost stage of the tower. The roof is supported by arcaded teak posts, and the floor is laid with the same kind of wood, in the manner of the deck of a yacht.

Adjoining the business-room and communicating with it is the library, 42 feet by 20 feet. This room faces the east, and has three large and deeply-recessed square bay windows, and two fireplaces. The ceiling is formed of wrought oak joists on moulded bearers.

The drawing-room, with octagonal garden-porch, occupies the south-east corner of the building, and is about 50 feet by 20 feet. The dado is panelled in walnut, above which the walls will be lined with maize-coloured silk. The ceiling is ribbed and enriched with plaster.

Between the drawing-room and the library is a lady's lavatory and cloak-room, &c., and a staircase leading up to the boudoir and Lady Peek's room.

The dining-room, 37 feet by 20 feet, has a similar ceiling to that of the library. The walls are panelled to the height of the doors. In connection with it is a serving-room with hot-plate, and access thence to the office corridor.

The grand staircase is of marble with parapet wall and moulded coping of the same. This material has been very freely used throughout the house; some noble blocks of marble having lain for years on the Rousdon beach, became available for use when Sir Henry Peek acquired the foreshore rights.

Close to the main entrance is the billiard-room, with a square bay window. Adjoining this is a lavatory, cloak-room, and water-closet for gentlemen, with a hot-closet for drying wet clothes.

Passing now through the folding doors which shut off the office corridor from the reception-rooms, a suite of three rooms are arranged as sitting-room, bedroom, and dressing-room for an invalid or for a visitor to whom the fatigue of ascending and descending stairs would be undesirable. Part of the dressing-room is partitioned off to form a water-closet, and a bath is also provided.

On the opposite side of this corridor is the butler's pantry, with plate-room and bedroom adjoining. Next to this is a room for brushing clothes; next to this again is a room in which the arrangement of flowers for the table and other like

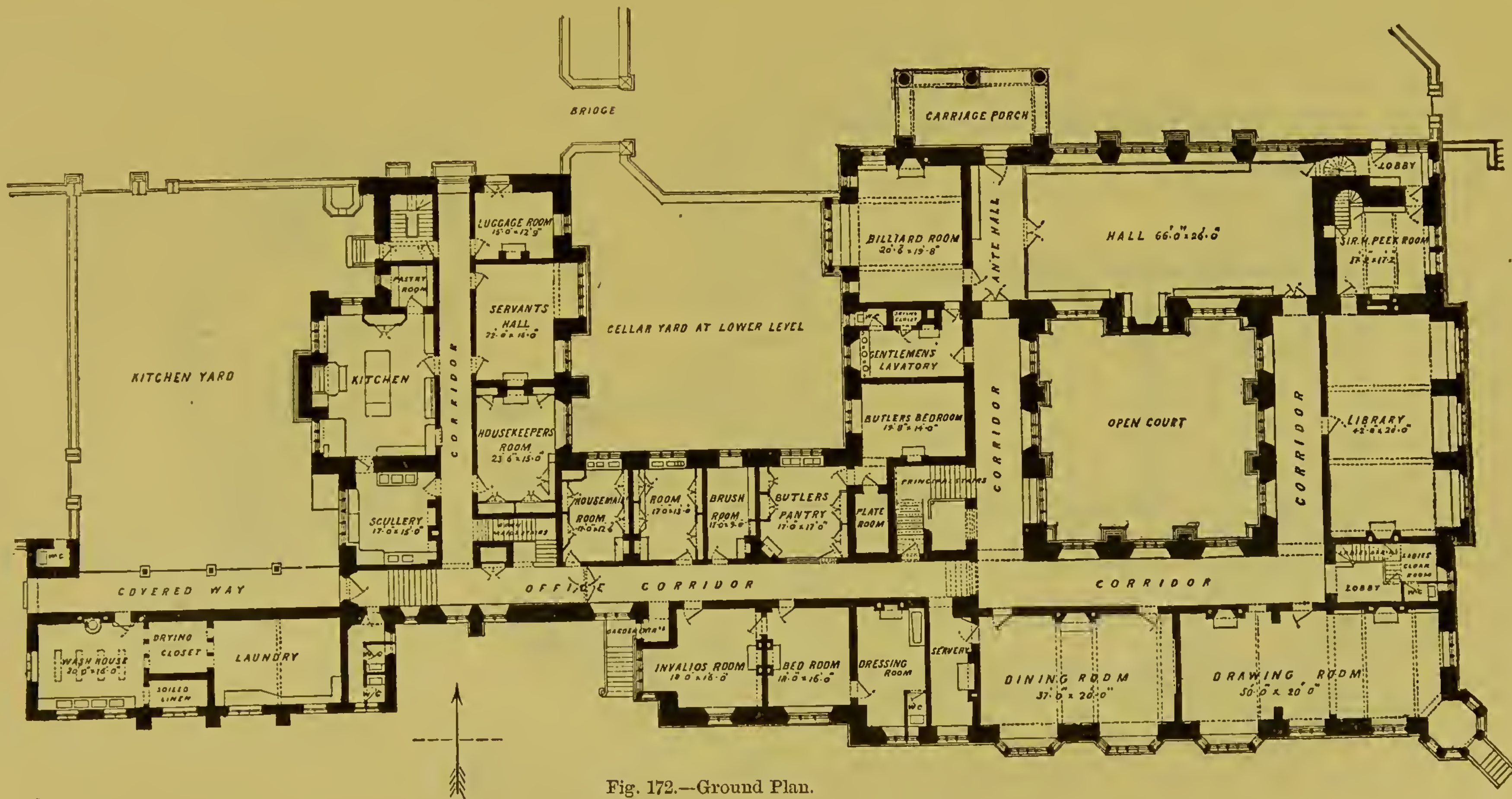
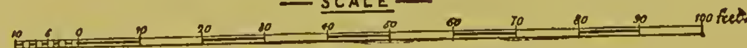


Fig. 172.—Ground Plan.

— SCALE —



Rousdon, Devonshire.

Fig. 173.—First Floor Plan.

SCALE

0 10 20 30 40 50 60 70 80 90 100 feet.

ROUSDON, DEVONSHIRE.

matters can be attended to by the lady of the house, and, finally, a housemaid's pantry. Both the last two rooms are provided with sinks and presses.

In the west wing the principal servants' offices are arranged. The kitchen, 26 feet by 20 feet, has an open timber roof, and besides the necessary appliances in the shape of range, hot-plate, ovens, &c., there is a lift for conveying coals from the basement. A serving-table and hatch afford convenient access to the corridor for serving purposes. Communicating on one side of the kitchen is a small room for preparing pastry, and on the other side is the scullery fitted up with steamers, sinks, &c. In the same wing are the housekeeper's room, servants' hall, and luggage-room. The last-mentioned room has an external door for the ingress and egress of luggage, this door being in the direct line between the main entrance and the stables.

The staircase at this end of the corridor gives access downwards to coal-cellar, lamp-room, and rooms for knives and boots, and upwards to the men-servants' bed-rooms; thus its use would be limited solely to the male servants.

An hydraulic lift rises from the basement to the top of the house for the carriage of coals, luggage, &c. This lift is placed in the centre of the maids' stairs, which communicate with the larders and bakehouse in the basement, and by corridors with the dairy, and with the bed-room floors above.

Separate closets and bath-rooms are provided for male and female servants.

In the basement the courtyard at this level is arranged in a cloister-like manner, the centre being occupied by the well already mentioned. The space under the great hall is utilised as a bowling-alley for American bowls. Under the library is the dairy. By the provision of windows both in the east and west walls a through current of air is insured. The fittings are of marble, the shelves being as much as 3 inches thick, in order to secure greater coolness. The walls are lined with a high tile dado, above which subjects are painted in blue of incidents associated with the dairy. The floor is of black and white marble. Adjoining is the dairy-scullery, provided with copper and sink for scalding pans.

The cellars are under the main reception-rooms, and include wood-cellar and wine-cellars, with dispensing and receiving cellars.

Two larders, one specially for game, a bakehouse and a beer-cellar, complete, with those rooms already referred to, the basement accommodation.

The bed-rooms are arranged on the two floors above the ground storey. The floors of the principal corridors of these storeys have interesting designs in marble mosaic, executed by the female convicts at Woking.

The materials employed for the walls are chert and large grey flints for the outer facing, with an inner lining of 9-inch brickwork, the latter being separated from the flint by a vertical course of asphalte 1 inch thick. The quoins and mullions of the windows are of Purbeck stone. The ashlar work inside the hall, and the stonework of the various moulded arches, is from the Beer quarries, Devon. The roofs and weather-tiling are of Bridgewater tiles. The chimney-stacks are built with Fareham red bricks.

The wood principally used in outside work, gables, half-timber work, &c., is teak.

The floors of the principal reception-rooms are of oak or parquetry, and the panelling and joinery through the greater part of the house, including all the

principal bed-rooms, is of wainscot, walnut, teak, mahogany, or cedar. The woodwork of the offices and inferior bed-rooms is of pitch-pine.

Connected by a covered way with the servants' wing is the laundry. This building comprises washhouse, soiled-linen room, drying-closets, and laundry, respectively fitted up with the necessary appliances.

The stable buildings are ranged round a courtyard, in the centre of which is a marble tank and fountain, surmounted by a hanging lamp on copper standards.

The yard is entered by an archway under a clock-tower. In this tower is a carillon with ten bells, fitted with a key-board on which the bells may be played after the fashion of the carillons in the old Flemish belfries.

The stables are divided into "own" and "strangers'" stables, the former being entirely loose-boxes. There are also boxes for the isolation of sick horses.

Harness-rooms, cleaning-rooms, men's rooms, and cottages for coachmen, are all provided.

Planned in connection with this group of building is a fives-court approached from the garden, and in connection with it is a dressing-room, lavatory, &c.

The scheme for drainage provides for the separation of sewage, storm-water, and rain-water from roofs.

The supply of drinking-water is from the ancient well before mentioned, and a stream below the house, means being provided of collecting, settling, filtering, and pumping.

Other buildings on the estate comprise farm buildings, carpenters' workshops, smithy, slaughterhouse, kennels, dwellings for bailiffs and other farm-servants, and gas-works.

AN OLD HOUSE RE-MODELLED.

Examples of various houses arranged so as to secure the most wholesome conditions have now been given, in which certain principles are embodied as being essential to health; it will, therefore, be interesting to examine the plans of a house situated in one of the most fashionable parts of the metropolis—a house that was erected probably about the close of the last century, and has been occupied by eminent statesmen and diplomatists, as well as by a princess of the royal family. At the commencement of its occupancy by the latter, its sanitary arrangements were improved under the direction of Mr. Aitchison, A.R.A., as well as was possible without very considerable re-construction. The accompanying plans may suffice to show the hopelessly bad arrangements as they existed prior to that period; and in this respect they serve to indicate what, down to a very recent period, was considered harmless even where expense was comparatively unimportant. The arrangements can be studied now as examples to be avoided.

Beginning, then, with the basement storey, it will be seen that the men's water-closet, with the dust-bin, occupied one of the vaults beneath the pavement of the street. It was absolutely devoid of light, and had no other ventilation than was admissible by the door from the cellar through which it was entered and an opening into the dust-bin. The maid-servants' closet is in a small yard. On the ground floor a water-closet adjoins the dining and waiting-rooms, being entered directly from the latter, while its soil-pipe descended through the larder in the basement. Another water-closet between the school-room and a bed-room was so placed as to

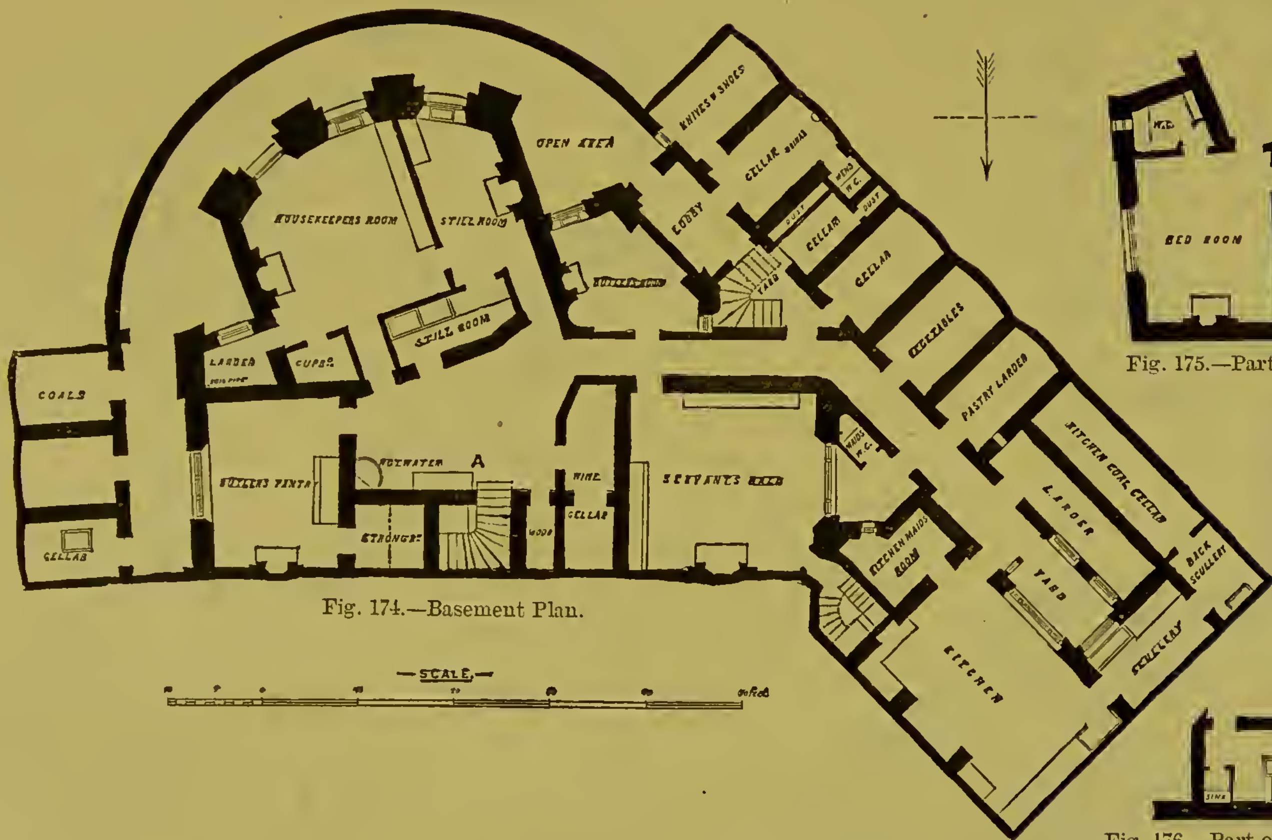


Fig. 174.—Basement Plan.

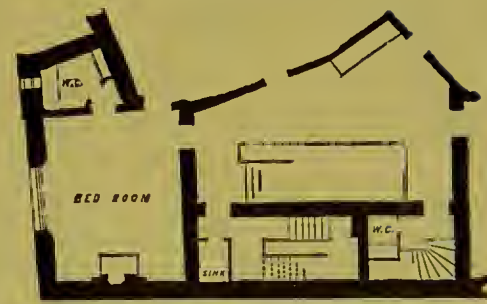


Fig. 175.—Part of Second Floor Plan above A.

Fig. 176.—Part of Third Floor Plan above A.

Old House Re-modelled.

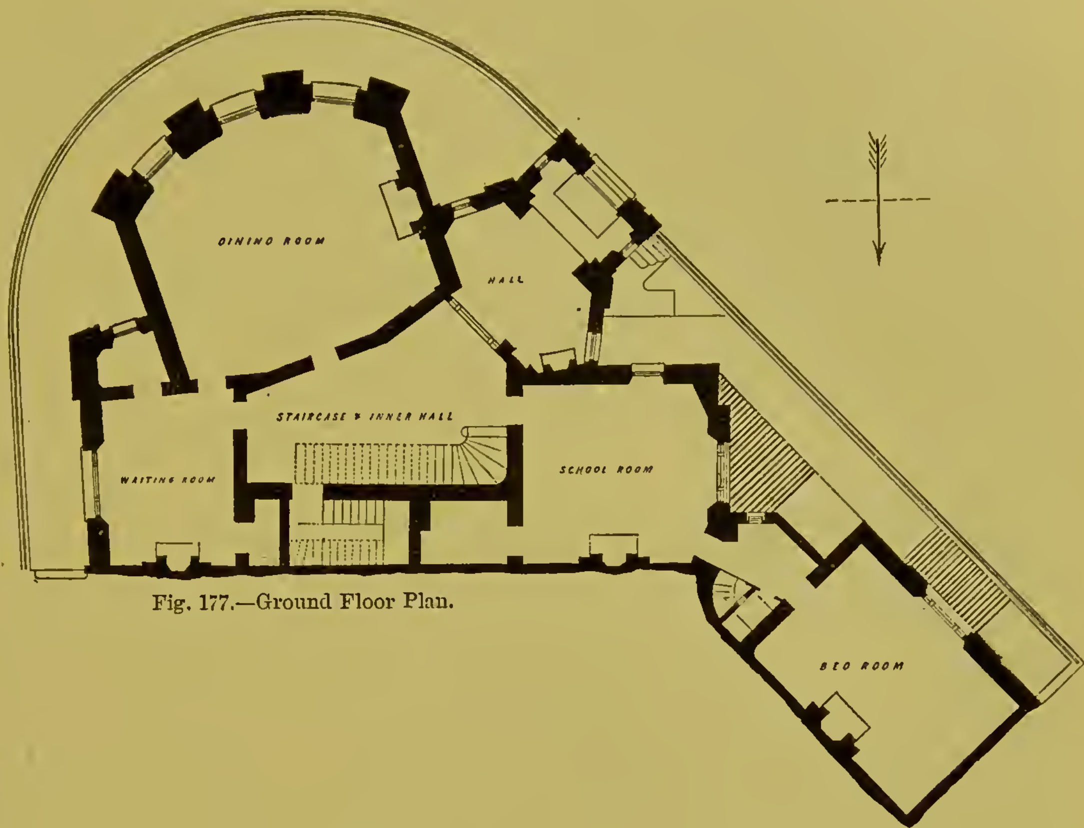


Fig. 177.—Ground Floor Plan.

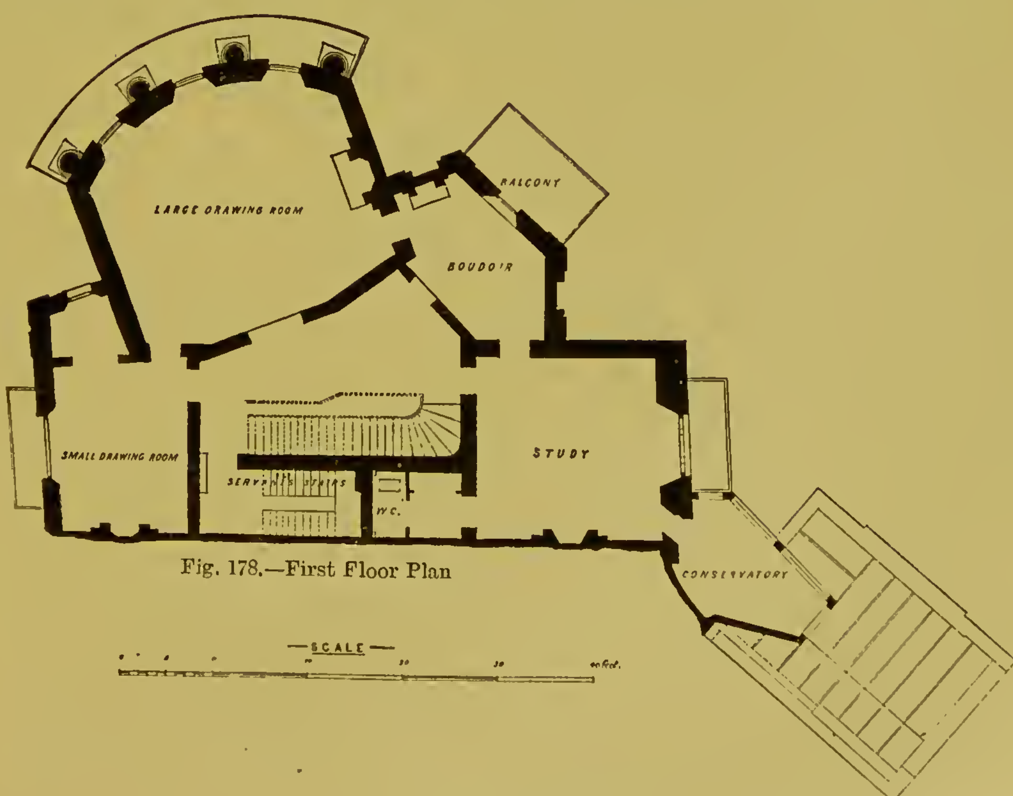


Fig. 178.—First Floor Plan

OLD HOUSE RE-MODELLED.

have no direct communication with the external air; it had a borrowed light on to the adjoining back stairs, which themselves were but imperfectly lighted. The one water-closet on the first floor opened out of the study, and was absolutely without light, and it had no ventilation save what it received from the study. On the second floor were two water-closets: one opening out of a bed-room, without any properly-ventilated lobby separating it therefrom, and its soil-pipe passing down through the larder in the basement; and the other under the steps of a back staircase, and wholly without light and ventilation. The housemaid's sink-closet on this floor was also totally unprovided with light and ventilation. The water-closet, again, on the third floor, and the sink-closet, were both quite dark and unventilated, except into the house itself. It will thus be seen that of the eight water-closets, five were totally dark and unventilated, and both the sink-closets were in the same condition.

Although none of these closets were permitted to be wholly removed, their condition was improved to a considerable extent by the judicious introduction of good apparatus, and sundry reflectors and shafts for light and air. White tiles and Hyatt's lights were introduced in the men's closet in the basement; a good porcelain urinal was substituted for the old tin one in the men's cellar; borrowed lights and glass lantern-lights were formed in some of the other closets; improved sinks were fixed in the housemaids' closets, the waste-pipes being ventilated and arranged to discharge in the open air. Other sanitary improvements were likewise effected, such as arranging cistern overflow-pipes to terminate in the open air; all inside drains were examined, tested, re-laid where necessary, and embedded and covered with concrete, and internal gulleys and connections with drains entirely done away with. In these and other ways the wholesomeness of the house has been made as satisfactory as possible, short of almost entire reconstruction.

CHAPTER XXIII.

NATURAL AND ARTIFICIAL STONES.

Granites—Slates—Marbles—Sandstones—Limestones—Portland Stone—Bath Stone—Various Kinds of Artificial Stone.

THE several precautions which should be observed in selecting a durable stone for building have already (pp. 52—56) been described. It may now be convenient to supplement those remarks by a somewhat more detailed description of the various kinds of stone available in this country for building purposes.

Building-stones may be divided into three classes : granites, schists, and trappean rock; sandstones; limestones.

Granite is classed by geologists among the igneous rocks, and, as far as has been yet ascertained, is one of the oldest rocks of the earth's crust. It is a compound, subject to variations, of quartz, mica, and felspar, and it occurs in large mountain masses, or in veins bursting through, and altering the newer adjacent formations.

There are various kinds of granite, the difference being caused by variations in the component minerals. When hornblende is substituted for mica the rock is called syenite. When both hornblende and mica are present the rock is called syenitic granite.

An excess of felspar produces a rock that is readily decomposed by exposure to the air and weather. The material known as kaolin, or china clay, is produced by the decomposition of a felspathic granite found in Devonshire and Cornwall. Some 40,000 tons of this clay are annually collected in these counties for use in the manufacture of pottery and porcelain.

The best varieties of granite in use in Great Britain are found in Scotland. Of these the best known are Aberdeen, Peterhead, and Ross of Mull. The Cornish and Devon granites are not, as a rule, so durable as the Scotch varieties. When carefully selected, however, they are durable and beautiful stones. Many very beautiful varieties of granite are found in Ireland.

From its great cost, both in the rough and in working, granite is not adapted, except in the immediate neighbourhood of the quarries, for general use in domestic work. It is largely used as a building-stone in Aberdeen and other places in the localities where it is found. Many of the old churches in Brittany are built of granite, and the mouldings and tracery are as clear and perfect as the day they were cut.

Granite is susceptible of a high polish, and is well adapted for chimney-pieces and other works of a decorative character.

Igneous rocks other than granite.—This class of stones is of small importance for architectural purposes. It comprises the several varieties of the trappean rocks (basalt, porphyry, greenstone, felstone, &c.), and the volcanic rocks (lava, basaltic lava, obsidian, pumice, &c.). Some of the varieties of porphyry, basalt, and greenstone make fairly good building-stone, but from the difficulty of working and

their usually sombre and unattractive appearance they are not generally suitable for architectural purposes.

Of the volcanic rocks it is only necessary to notice pumice, a "light porous rock evidently produced by the disengagement of gases in the mass while in a state of fusion; in other words, the solidified froth or scum of molten rock matter."* Pumice is used in polishing wood, stone, metal, glass, and ivory, and by painters for rubbing and cleaning down their work. Puozzolana, a recent volcanic tufa, is employed in the manufacture of cement.

Metamorphic or altered rocks.—Rocks originally sedimentary, but which from various causes have undergone changes which have entirely obliterated all traces of organic life (if such ever existed), at least so far as our present knowledge extends, are called metamorphic or altered rocks (Gr., μετα, change, and μορφη, form). The rocks belonging to this class are all more or less crystalline, and present many different evidences of the influences to which they have been subjected. They are rarely stratified, but are frequently bent and folded into every imaginable form. Some present strong lines of cleavage, such as the slates used for roofing purposes. Others, again, as serpentine, have the appearance of marble; while graphite, which is probably an altered form of anthracite, is the amorphous material so well known as black-lead.

The rocks of this class of most service to the builder are the slates. The ordinary slate used for roofing and other purposes is an altered form of clay of fine texture, originally deposited, in all probability, as a fine-grained silt, and subsequently subjected to enormous compression. Embedded in it are frequently found cubes of iron pyrites, chert or siliceous concretions, and crystals of hornblende, augite, and chiastolite, a mineral occurring in long, slender prisms, which cross and lie over each other like the Greek letter χ (χιαστος, crossed, and λιθος, a stone).† These cubes of iron pyrites are sometimes made the ground of objection to the slates containing them, it being supposed that they are liable to fall out, and so leave holes or empty spaces. This objection is not, however, very serious, as slates with these embedded cubes have been known to last for many years without signs of injury. The special value of slate for roofing purposes is the ease with which it can be split along the planes of cleavage.

Serpentine is described by Mr. Page as "an intimate admixture of various magnesio-siliceous ingredients (chlorite, steatite, diallage, lince, &c.), which produce a rock of a speckled or mottled appearance resembling a serpent's skin; hence the name Serpentine." In colour, serpentine is usually red or green, with veins of white blotches and streaks of green, blue, and red. Some varieties are clouded. The best-known variety, from the Lizard, in Cornwall, has a dark olive-green ground, with streaks of blood-red mixed with other tints.

Serpentine is much used for interior decorative purposes, but is totally unfit for outdoor use on account of its bad weathering qualities.

Besides the well-known Cornish serpentine, this stone is found in Wales (Anglesea), Scotland (Portsay, Aberdeenshire, and the Shetland Isles), and in Ireland. The Connemara or Irish green marble is a variety of serpentine.

The other varieties of metamorphic rocks are of little importance as materials for architectural purposes. The metamorphosed limestones yield marbles which,

* Page, "Advanced Text-Book of Geology," p. 138.

† Page, "Advanced Text-Book."

from their crystalline texture and veined appearance, are in great request for sculpture. The purest white marble comes still, as it did when Michael Angelo made journeys to the quarries to select his own blocks, from the famous quarries of Carrara.

The mica schists, gneisses, and chlorite schists, are, in some localities where ordinary building-stones are scarce, employed in building, but, though durable, they are very unsatisfactory in appearance.

Steatite, or soapstone, is useful for ornamental purposes—such as inlaying, and for vases.

Next in order comes the important group of building-stones known as sandstones.

Sandstones consist for the most part of grains of quartz (silica), cemented together by silica, carbonate of lime, carbonate of magnesia, and oxide of iron, in varying proportions, or by combinations of these substances. They vary in texture, colour, and durability, to a very great degree, the nature of the cementing material being the chief element of strength or weakness.

The following classification is made of the several varieties of sandstones:—

Liver rock.—The best and most homogeneous stone, and which can be obtained in the largest blocks without joints, "thick-bedded."

Flag-stones.—Laminated stones, which split easily along the lines of bedding, used for paving-stones.

Tile-stones.—Thinner-bedded stones than the last; used in some localities for roofing.

Freestone.—A term applied equally to limestones and sandstones which are easily wrought.

Grits.—The coarser varieties from the well-known millstone-grit formation; strong, hard, and durable stones.

The best test of the wearing quality of a sandstone under ordinary atmospheric conditions, apart from special circumstances—as the smoke in towns, emanations from factories, &c.—is the weathered face of the stone in an old quarry or cliff, or in some old building. In the report (16th March, 1839) of the Commissioners* for selecting the stone to be used in building the new Houses of Parliament, several interesting particulars are given of the condition of the stonework in old buildings, from which the following is an extract:—

"Of the sandstone buildings which we examined, we may notice the remains of Ecclestone Abbey, of the thirteenth century, near Barnard Castle, constructed of a stone closely resembling that of the Stenton quarry in the vicinity, as exhibiting the mouldings and other decorations, even to the dog's-tooth ornament, in excellent condition. The circular keep of Barnard Castle, apparently also built of the same material, is in fine preservation. Tintern Abbey may also be noticed as a sandstone edifice that has, to a considerable extent, resisted decomposition, for although it is decayed in some parts, it is nearly perfect in others. Some portions of Whitby Abbey are likewise in a perfect state, whilst others are fast yielding to the effects of the atmosphere. The older portions of Ripon Cathedral, constructed of sandstone, are in a fair state of preservation. Rivaulx Abbey is another good example of an ancient sandstone building in a fair condition. The Norman keep of Richmond

* The Commissioners were Dr. William Smith, Mr. (afterwards Sir Henry) De la Bêche, Mr. (afterwards Sir Charles) Barry, and Mr. C. H. Smith.

Castle, in Yorkshire, affords an instance of a moderately hard sandstone, which has well resisted decomposition.

"As examples of sandstone buildings of more recent date in a good state of preservation, we may mention Hardwicke Hall, Haddon Hall, and all the buildings of Craigleith-stone in Edinburgh and its vicinity. Of sandstone edifices in an advanced state of decomposition, we may enumerate Durham Cathedral, the churches at Newcastle-upon-Tyne, Carlisle Cathedral, Kirkstall Abbey, and Fountains Abbey. The sandstone churches of Derby are also extremely decomposed; and the church of St. Peter's at Shaftesbury is in such a state of decay that some portions of the building are only prevented from falling by means of iron ties."

The facts recited in the foregoing extract show pretty clearly the durability of certain kinds of sandstones, and the importance of exercising the greatest care in selection. It should also be noted that in the case of several of the buildings referred to above, the roofs and windows have long since been removed, and the masonry subjected to the severest possible test of the durability of the stone employed in its construction.

The Stenton or Stainton stone, mentioned as employed in the construction of Ecclestone Abbey and Barnard Castle, is a light-brown sandstone from the coal measures. The sounder parts of Whitby Abbey are built of a new red sandstone called Bottom Quarry from Aislaby, Whitby. Tintern is built with a stone from the old red sandstone formation known as Barbadoes, quarried at Chepstow.

As a rule, the fine-grained sandstones are the most durable, though some of the coarse grits are of great durability. The millstone-grit, before referred to (the "farewell-stone" of the coal-miner), is the most durable of the coarser-grained varieties. The sandstone which, in Caernarvon Castle, alternates with the limestone is probably millstone-grit.* Sandstone not unfrequently contains nodules of iron pyrites. When this is the case the stone is not fit for use in facing, as the iron oxidises and weathers out into holes.

In the "Notes on Building Construction," Part III., a Table is given, showing the results of experiments on the relative amount of absorption in different sandstones. Of seven different kinds of stone tested, the per-centage of absorption varies from 8·00 in Craigleith-stone to 20·00 in Hassock. These two stones represent the two extremes, Craigleith-stone being one of the most valuable sandstones, and Hassock about the very worst.

Between these two extremes are several qualities of stone, many of which are durable and safe stones to be used, provided always that judgment and discretion be exercised in selecting the blocks. As examples, Park Spring, the best beds of Mansfield, Heddon, Bramley Fall, Forest of Dean, and many of the Yorkshire and Scotch varieties, may be mentioned.

Besides these, there are many varieties of sandstones only locally used. In the Wealden district, for example, are many very useful and durable stones, of one or other of which most of the old churches in the locality are built. Much valuable information on local stones and quarries, and their weathering qualities, is contained in the "Memoirs" of the Geological Survey.

Limestones.—Limestone is a term applied to rocks the greater part of which consists of carbonate of lime. The group of stones coming under this head may

* Ramsay, "Physical Geology."

be divided into five classes: compact limestone; shelly limestone; oolitic, or granular limestone; magnesian limestone; marbles.

Compact limestones are, as a rule, dull in colour, and non-crystalline in structure. The well-known Kentish rag is a member of this class. The Lias limestone, from which a most useful hydraulic lime for building purposes is obtained, is also a compact variety. This group is not of very great importance for general building purposes.

Shelly limestones consist of vast numbers of fossil shells naturally cemented together, and in many instances are sufficiently hard to take polish. Purbeck marble, so largely used in the interiors of our old cathedrals, and Sussex, or Petworth, marble, are examples of this class of stone.

The group called oolitic, or granular, from the appearance of the stone, which is that of egg-shaped grains cemented together, is perhaps the most important of all the limestone groups. The grains themselves, which vary in size in different stones, consist of carbonate of lime, and the cementing material is either the same substance, or a mixture of carbonate of lime with silica, carbonate of magnesia, or alumina. Portland, Bath, Caen—all well-known and extensively-used stones—are members of this group.

Magnesian limestones are those in which the proportion of carbonate of magnesia exceeds 15 per cent. The more nearly the carbonates of lime and magnesia approach equivalent proportions, the better is the stone. When the proportion is that of one molecule of carbonate of lime to one molecule of carbonate of magnesia, the stone is called (after a French geologist, Dolomieu, who first noticed this stone in the Alps) dolomite. The greater durability of this stone is probably due not so much to the increased amount of magnesia in it, as to the fact that instead of being composed of different sorts of crystals—some formed of carbonate of lime, and others of carbonate of magnesia—the entire mass is made up of rhomboids, each of which contains both substances homogeneously crystallised together.* The celebrated quarries of the Mansfield district yield several varieties of magnesian limestone, of which that known as "Mansfield Woodhouse" most nearly approaches the proportions of dolomite. Bolsover Moor, Anston, and Roche Abbey are durable stones of this class.

All limestones which are of sufficient hardness to take a polish are called marbles. Many of this group are highly fossiliferous, and some, such as the encrinital marbles of Derbyshire, are known by the name of the most conspicuous fossil embedded in them. The best-known varieties are those of Devonshire and Derbyshire. From Ireland varieties of useful and beautiful marble are obtained.

Limestones, like sandstones, vary very greatly in their weathering qualities. A notable instance of this is to be found in the city of Oxford. There the extremely decayed condition of the stonework of many of the colleges and other buildings is remarkably conspicuous, whilst, on the other hand, some of the buildings, particularly the chapel of Merton College, are as well preserved as others are decayed. The reason of this is to be found in the fact that two different kinds of stone have been used—one, a shelly oolite, in all probability Tainton stone, which has weathered well; the other, a soft, friable, coralline oolite from

* C. H. Smith's "Lithology," Transactions of R.I.B.A., 1844.

Headington, which has largely decomposed. Caen stone, an oolitic limestone, is, except great care be taken with the selection, a very unsafe stone for outside work. In Mr. Henry Thomas Hope's house* at the corner of Down Street and Piccadilly (now the Junior Athenæum Club) the stonework was executed in Caen stone. Great care was exercised in the selection of the blocks, and the projecting mouldings and cornices were covered with thin sheet lead, with the most satisfactory results.

Portland stone is one of the most valuable of all the building-stones we possess. It has been used for almost all important buildings in London from the beginning of the seventeenth century until the present time, and the experience of that period certainly warrants its being placed in the front rank both for appearance and durability. St. Paul's Cathedral is built of this stone, and the care with which Sir Christopher Wren selected the blocks for actual use is evidenced to this day by the blocks discarded by him still lying in the vicinity of the quarry. Most of the City churches erected by Sir Christopher Wren are built of Portland stone, and, as a rule, have withstood the ravages of the London atmosphere well.

Several qualities of stone are obtained from the Portland quarries, the most valuable being known as the True Roach, Whitbed, Bastard Roach, and Base Bed. Of these, True Roach is the best for heavy structural purposes and for rough masonry. It is distinguished from Bastard Roach by the presence of a small fossil univalve shell, called by the workmen the Portland Screw (*Cerithium Portlandicum*—Fig. 179).

Fig. 179.—C. Portlandicum.

Whitbed is the most useful for general purposes. Close and fine in texture, it is hard, and weathers well.

Bastard Roach is like True Roach in the fact of its being generally very fossiliferous. It is, however, a much inferior stone, and not fit for use in exposed situations, or where it would be liable to much traffic or wear.

Base Bed is softer than either of the foregoing, and is only suitable for interior work. It is a good stone for carving, being easy to work and uniform in texture.

Chilmark, or Tisbury stone, is a useful stone, and of good weathering qualities. Salisbury Cathedral is built of this stone, and it was used in the restoration of the Chapter House, Westminster Abbey.

Bath stone is perhaps the most widely-used building-stone in this country. It varies very considerably in quality, some varieties being quite unfit for exterior work, whilst others stand the action even of the London atmosphere fairly well. The best bed is that known as Box Ground. Some beds of Combe Down weather well, others badly. Farleigh Down and Corsham Down are both soft stones, fit only for interior work. Corsham Ridge is a newly-opened quarry, the stone from which was used in the facing and carved pediments at the Westminster Aquarium. Its weathering qualities have yet to be ascertained.

Kentish Rag, a compact limestone, is an excellent stone for rubble work. Both for appearance and durability, it should always be used with a rough hammered face, not tooled.

* Mons. Dusillion and Professor Donaldson, joint architects.

The report of the Commissioners for selecting the stone for the Houses of Parliament, before referred to, recommends the use of limestones in preference to sandstones, "on account of their more general uniformity of tint, their comparatively homogeneous structure, and the facility and economy of their conversion to building purposes."

It may also be taken as a fact that limestone is ordinarily more reliable under the influence of fire than sandstone. In an experiment made after the destruction by fire of old Doncaster Church, it was found that while a large block of sandstone flew to pieces after being placed in a fire but a short time, a similar block of limestone was only superficially calcined after twenty-four hours' exposure to the flames.*

The various kinds of artificial stone which have been introduced, with a view to provide a durable material for use in localities where natural stone is difficult to procure, call for some description here.

Ransome's artificial stone is practically a sandstone, the constituent parts of which are similar to those of Craigleith stone. Flints dissolved by means of caustic alkali under high pressure are mixed with fine sharp sand in a pug-mill, and the viscous tenacious substance that results is moulded into the desired forms. The blocks, when turned out of the moulds, are first saturated with a cold solution of chloride of calcium, and then immersed in a hot bath of the same. The silicate of soda (the result of the dissolved flints) and the chloride of calcium coming in contact instantaneously decompose, the silica combining with the calcium to form silicate of lime, the cement which binds the materials together, whilst the chlorine and soda, together forming chloride of sodium, are subsequently washed out.

The result of this ingenious and interesting process is a fine-grained homogeneous sandstone which can be carved and dressed like the best kinds of natural stone. The facility with which the substance, when in a soft state, can be moulded to the most delicate forms desired is one of the chief advantages of the process. In fact, it is this quality which makes the use of artificial stone possible, as for ordinary blocks the cost is somewhat more than that of most natural stone.

"Apænite" and Victoria stone are varieties of artificial stone with slightly different component parts. Victoria stone has been extensively used for paving purposes, and was employed for the whole of the external stonework, except the cornice, at Fresh Wharf, London Bridge; and also for parts of Messrs. Peak and Frean's biscuit factory at Bermondsey.

Chance's artificial stone is made by melting the Rowley Rag, a basaltic stone, found in the Rowley Hills, near Dudley, in Staffordshire, and then casting it into the required shapes.

Rust's vitrified marble is a mixture of glass and sand fused together and moulded in metal moulds. Colour is added when the substance is in a semi-fluid state, by mixing with it oxides of the various metals. It is also used in small tesseræ for marble mosaic.

* Becket, "Book on Building."

CHAPTER XXIV.

REPAIRS AND ALTERATIONS.

Need of Strict Examination—Landlord and Tenant—Damp—Roofs—Painting—Minor Repairs.

A SUBJECT which interests most occupiers of houses of every class, and one which is intimately connected with the conditions combining to make a house healthy or the reverse, as well as comfortable, is that of repairs.

Dwelling-houses, especially those of the smaller type of suburban villa, are more commonly built with a view to a speedy sale than to lasting out the term of their leases, or to fulfilling the conditions proper to healthy habitations.

The protection, moreover, which the law is supposed to afford to purchasers and tenants, against scamping and dishonest workmanship, the use of improper materials, and the disregard of all sanitary laws—sins of omission and commission common to so many builders of the speculative class—is unfortunately in very many districts entirely wanting. Some progress, however, has been made in recent years in the right direction; but while local boards and vestries are discussing various points of detail in their proposed bye-laws—occasionally with the avowed object of delaying the adoption of the regulations, in order that the local builders may be unshackled as long as possible—houses are being run up by the score, doomed to be a never-ending and constantly-increasing source of expense to their unfortunate purchasers, an annoyance to their occupiers, and threatening to perish from premature decay long ere the term of the ground lease has run its course.

Under these circumstances, it behoves every intending tenant or purchaser to make the most searching examination he can of the house he purposes to inhabit. In the case of a tenant, he must learn the all-important lesson that the law recognises the implication of no covenant or promise on the part of the lessor that the house proposed to be let is even reasonably fit for habitation, or that it will endure during the term of the intended lease. Nothing can be more distinct than this, and the very harshness of its operation should of itself deter tenants from rashly saddling themselves with unseen and undreamt-of liabilities. Even in the case of a house let on a yearly agreement, in the absence of any express stipulation to the contrary, the landlord is not bound even to maintain the roof over his tenant's head; neither is he bound to keep the drains in proper condition, or to uphold or repair the premises in any way. Hence the necessity for tenants to insist upon proper stipulations in their agreements; or if themselves undertaking the repairs, to protect themselves by taking competent advice as to the structural and sanitary conditions of the house to be leased. Hence, also, the great importance of some proper and vigilant supervision on the part of the local authorities over the construction of dwelling-houses, especially those destined for the occupation of the middle and poorer classes. The Legislature has given them ample power to deal with such matters, and it only remains with them to assume those powers and to conscientiously carry them out.

On the other hand there is on the part of the tenant an implied covenant to

uphold and maintain, notwithstanding the absence of any express covenant to that effect.

The usual form of covenant to repair, as inserted in leases for terms of years, is most comprehensive, and though it varies somewhat in stringency in different leases, it may be taken as a rule to require the house and premises demised to be kept in fair tenantable condition, with little or no allowance for wear and tear. It is true that legally a tenant, in repairing, is not bound to use new materials. The distinction is, however, in practice very slight: so slight, indeed, that as a matter of fact it is never observed; and the landlord may, and often does, succeed to a house little, if at all, deteriorated in value since the granting of the lease.

All this sounds, and frequently is, very harsh and exacting upon an outgoing tenant. There is all the more necessity, therefore, for a strict adherence to the caution above given of examining well and carefully the condition of every part of a house about to be inhabited.

To proceed, then, to the consideration of the parts to be most critically examined, and the methods to be adopted in such examination.

Obviously the first point to which attention should be directed is the system of drainage. If all drains were laid as they ought to be, and as, with but little additional outlay, they might be, there would be no difficulty whatever in ascertaining in a very short space of time in what position and in what condition they were; indeed, it would be well if every intending purchaser or tenant were to insist on actually seeing the whole course of the drains; and if this be impossible, he should require the lessor to take them up, and relay them in straight lines, and with uniform gradients between the several points where changes of direction or gradient are necessary, so that by means of suitable inspection-holes they could at any moment be examined. Of course, these improvements in the drains of the house will have to include suitable means of shutting off the passage of air from the public sewer into the house drains.

There will undoubtedly be much difficulty for some years to come in the adoption of such a course, inasmuch as it has not hitherto been customary for the speculating builder to anticipate such a proceeding on the part of the would-be tenant, and therefore he is at present more or less master of the situation, and must be expected to do his best to remain so. But if the public are led to demand proper arrangements, such arrangements must ultimately be provided. Under the existing conditions, unfortunately, instead of drains being laid in accessible positions wholly exterior to the house, and in lines the most direct possible, they are usually carried at haphazard, according to the judgment of the jobbing drain-layer, and laid from point to point as they happen to be wanted, with curved bends and extemporised junctions innumerable; and very frequently they are placed under the floor of the living-rooms, perhaps resting on, instead of being buried in, the ground. Means of access are not even thought of, much less provided, the only thought apparently being to hide all traces of them, and to render the search which will inevitably have to be made as difficult and as costly as possible. In a future chapter will be found described how a drain ought to be laid; it is merely necessary here to point out that without proper means of access to at least two points in the drain of even the smallest house, that house cannot be said to be properly complete. The intending tenant or purchaser should, however, do more than insist upon proper means of

access to the drain being provided; even if the expense have to be borne by himself, he should have the drain opened at two points and "tested:" that is, filled with water, the lower end first being stopped with clay or by other means, in order to ascertain if any leakage exists in any part. The presence of a leak will immediately make itself known, either by its being found impossible to completely fill the drain, or by the water slowly wasting away after the pipe has been filled.

While on the subject of drains, the intending tenant will do well to examine carefully all the traps and water arrangements, to see how far they tally with the principles of sound sanitary conditions. So far as many of these arrangements are concerned, some help is in many places now afforded to tenants and occupiers by the regulations of the water companies for the prevention of waste of water. The officers of these authorities usually look carefully after the fittings and waste-pipes, and insist upon builders complying with their regulations; and those regulations are, as a rule, based upon sound principles of sanitary construction. One of the commonest sources of expense and annoyance is the water-supply pipe. Frequently of insufficient substance of metal, fixed in the most exposed positions, and with weak and faulty joints, what wonder that with every severe winter one part or another bursts, and floods ceilings, walls, and floors? The ball-valve, too—that bugbear of householders—either refuses to shut off the water, or when the cistern is empty declines to fall, and so prevents the ingress of the water. These and many other evils, such as the leakage of taps, which the plumber, when called in to examine, pronounces to want "grinding in"—an operation which he performs periodically, greatly to his own benefit, but at a cost to the householder somewhat greater than that of a new tap—are only to be obviated by the proper provision at the outset of everything of the best and most durable quality.

An intending tenant or purchaser of a house, who is limited in point of locality to a certain given neighbourhood, cannot, of course, exercise much discretion in the matter of site. He can, however, take some steps to ascertain whether the ground on which he proposes to dwell has or has not been the place of deposit for the vegetable and other *débris* of the neighbourhood. He can also, if he take timely precaution, insist upon the surface of the ground under the floors being covered with concrete or other impervious material, to prevent the evils arising from the exhalation of ground-air or ground-moisture into his dwelling.

He can further, by careful examination, ascertain whether a proper damp-proof course has been introduced in the walls of his house, and if the ground has been raised above the level of the damp-course, he can have it removed, and either lower the level of the ground near the house, or have a dry area formed round it, in the manner described in the earlier part of this work. If his house has been built without the insertion of a proper damp-proof course in the walls, it will be worth consideration whether the house deserves his further attention. From the conditions of the site and the character of the subsoil, it may be that but little damp will rise in the walls, or the walls themselves may be constructed of exceptionally hard and impermeable materials; otherwise, if the house is one that possesses so many important advantages that no other will suit, it may be worth while to have a damp-proof course inserted

in the walls—a process involving much care and patience on the part of the person employed to do the work, but nevertheless one that is quite possible, though it may involve what may be regarded as a rather considerable expense. It can hardly be expected that the ordinary householder, who perhaps considers himself not justified in incurring the expense of employing a competent professional adviser, should with any advantage to himself be able to exercise judgment in the matter of such materials as bricks, stone, and mortar. He can, however, recognise lime when he sees it, and he can also discriminate between sand and road-sweepings. It will therefore be competent for him to prevent the use of the latter material in the formation of mortar. The salient characteristics of good bricks and stone have been described in a preceding chapter; further information than what is there contained can hardly be of service, as without experience and practice all theories are of little practical value.

If the external walls are formed of such pervious materials as to let driving rain penetrate them, the remedy will have to be sought in the application on the outside of some impermeable material, such as good Portland cement, tiles, or slates laid upon battens fastened to the walls. In some instances the walls may with advantage be pitched, or they may be painted—a process, however, which is rather costly, and must be renewed at somewhat frequent intervals.

If the householder would steer clear to the utmost of his power of all unnecessary repairs, let him by all means eschew houses into the external architecture of which stucco or cheap Bath stone enters. More fruitful causes of expense do not exist. The stucco, if it does not peel off or come away in large flakes, will at the end of a few years infallibly require painting—a process which the unfortunate owner will find to his cost has to be renewed every three years. The cheap Bath stone—of which, unfortunately, so much is now used in the suburbs of London to produce a showy and attractive appearance—is an even more objectionable material than stucco. It may safely be predicated of much of this kind of stone in suburban villas that it will within a very few years require to be entirely renewed: needless to say, at a very heavy expenditure.

Some of the most salient points on which a householder, unassisted by competent professional advice, may do something towards protecting himself against future repairs have been mentioned, and it cannot be too strongly urged that in house-building, timely prevention of decay by the substitution of sound materials and proper construction for inferior materials and scamping workmanship, is infinitely better and more economical than the cure of the evils resulting from these sources.

It must, however, happen to the best-built houses that repairs are at times necessary, and it will therefore be useful to notice some of the most frequent and important of these repairs, with especial reference to their bearing on the subject of health.

In most old houses, and particularly in those the roofs of which are covered with tiles, the roof is an ever-recurring source of trouble and expense. The wet perhaps penetrates through the ceiling of a particular room. The cause is searched

for, and probably traced to a broken or defective tile or slate; but in searching for and repairing this one leak, the workmen in all probability will leave double the damage behind them, in the shape of tiles or slates broken during their operations. In the case of plain tiles, the defects are not uncommonly caused by the decay of the laths, or the pins to which they are fixed, causing the tiles to slip down. When the laths decay, the roof, or the defective part of it, should at once be stripped, as otherwise there will be great risk of the decay, which spreads very rapidly, extending to the rafters. In re-tiling a roof, the best of the old tiles should always be re-used, as they are better as a rule than new ones; and care should be taken that each tile is properly fastened with two oak pins. Pan-tiling, which was once a favourite method of roof-covering for country houses, has fallen greatly into disuse, except for farm buildings and the like. The old glazed black pantiles of the last century make, however, very excellent roof-coverings, and if laid at a proper pitch, little can be said against them. The most general failing in pantiles is that they are laid at an angle much too near the horizontal, and depend greatly upon their pointing for keeping out the wet. When this is the case, it is necessary to exercise the greatest care in pointing the tiles. This should be done with a mixture of lime and hair and Portland cement; the mortar commonly used falls out after a very short time, and the roof is worse than if it had never been pointed.

A not uncommon cause of damp from the roof is the neglect to periodically examine and repair the joints of the brickwork of parapets and copings. When a parapet wall is coped with stone, and the mortar or cement joints between the stones get worn away, and are not promptly repaired, the wet will soak through these joints, and so down the wall, and will make itself visible by stains on the paper of the upper rooms.

So also with chimney-stacks; in course of time the mortar perishes and falls out, leaving the joints open; driving rain will then beat in, and soak down the brick-work into the interior of the house. All these defects can be prevented by timely precautions; periodical examination of roofs and chimneys, more particularly in the autumn and at the end of the severe winter months, can alone ensure anything like immunity from damage. For pointing open joints of brickwork, a mortar composed of the ashes from a smith's forge, sharp river sand, and Portland cement, is the most durable to be had.

While upon the subject of roofs, it should be noted that lead gutters frequently drop and become faulty in consequence of the decay of the woodwork which supports them. The cause of this decay is generally to be traced to the absence of ventilation to the woodwork. Lead is also subject occasionally to the attacks of a kind of worm, which eats through the metal. An instance of this was discovered at a church at Wandsworth, where the lead was actually riddled with holes eaten by these creatures.

Not the least important part of the present subject is that of painting: important not only on account of its value as a preservative for wood and iron from the effects of weather and the action of the air, but also from its cleansing and antiseptic properties. So important, indeed, is the periodical renewal of the paint on these materials, that it has been for many years past recognised by law, and to paint outside once in every three years, and inside once in every seven, are as invariable

stipulations in every lease as that the tenant shall pay the rent, or the landlord give the tenant peaceable possession.

Common as the custom is, the actual work is, however, frequently performed in a most improper and perfunctory manner. It is of very little use, for instance, to paint over a wall or a door covered with the accumulated dirt of three London winters without first cleaning the surface to be painted in the most thorough manner possible. Such a process may, however, be witnessed not unfrequently by those interested in such matters. Painting on old work, if it is to be efficiently done, must be on as clean a surface as it is possible to get; the surface should be well rubbed down and properly repaired. If during the preparatory process the material become exposed in any parts, extra coats of paint must be applied to those parts to bring the whole of the paint to an even level.

The foregoing may be said to comprise the parts of a house most generally and universally needing periodical repairs. There are, besides, many matters requiring careful attention from time to time, as the state of floor and roof timbers, the condition of brickwork, especially in exposed situations, and the state of all such fittings and appliances as water-closet apparatus, sinks, and the like.

The renewal of sash-lines, again, is a troublesome repair that is constantly recurring, and one that householders might themselves easily effect if they were willing to give the requisite time and trouble, and thus save the annoyance, not to say expense, of employing a jobbing carpenter for the purpose. By removing the beading which holds the lower sash in its place, and then prizing out the lower portion of the strip of wood that separates the places in which the two sashes slide, it will be found possible to take out what is called the "pocket-piece"—a loose piece of the boxing in which the balance-weights hang. When this piece of wood is removed, it will afford access to the iron weight, the cord of which has been broken, and which will be found at the bottom of the boxing. The sash involving the repair must be taken out, and the end of the broken cord removed, the end of a new one being nailed in its place in the same way as the old one. The new cord, which should be a stout hempen plaited one, not too large for the pulley, should then be passed over the pulley, and allowed to fall down the boxing inside the window-frame until its end can be got at through the pocket-hole, when it may be fastened to the balance-weight; this may then be replaced in the boxing, the pocket-piece put back in its place, the parting strip carefully replaced, and the sashes and beading returned to their original positions.

The enemy most to be feared in connection with woodwork is dry rot, a fungus which, once established, spreads over the surface of the timber like a skin, and with marvellous rapidity. The cause of its appearance is generally insufficient ventilation. It is, however, not unfrequently due to the fact of the timber itself being insufficiently seasoned. When it has once appeared, there is no remedy but to remove the whole of the old timber, and with it all traces of the fungus; well lime-white the walls before fixing the new timbers, and treat the new timbers with some efficient protective solution.

It sometimes happens that in exposed situations, and after unusually severe weather, rain will penetrate through walls in places that had hitherto been perfectly damp-proof. It will generally be found that the cause is due to the decay of the mortar joints, and the remedy for this is to rake out the joint, and well point with

smith's ashes and cement. If, however, the rain actually drives through the bricks, the best remedy to adopt is the use of one of the water-proofing solutions, of which there are several available. This course is held to be preferable to covering the wall with cement stucco, as, while preserving the interior from damp, it is alleged that it does not interfere with the porosity of the bricks—a point of considerable importance.

The last point to be mentioned—the condition of water-closet apparatus, sinks, and other fittings—is one to which too much attention can hardly be paid. Water-closet basins, even of the best construction, require to be cleaned regularly, or they become foul and offensive. This is more particularly to be observed in the case of pan-closets, where from any cause such objectionable things are perforce retained. A periodical cleansing with a hard brush and strong soda and water or spirits of salts will go far to lighten the evils inseparable from this class of apparatus.

CHAPTER XXV.

THE ARCHITECT AND ARCHITECTURE.

Origin of Architecture—Its Elements—Convenience, Strength, and Beauty—Effect on Architecture of Climate and Materials.

At whatever period of time man first made his appearance on this island, it may fairly be assumed that amongst his first wants would be that of a shelter from the inclemency of the weather. The most primitive type of man of whom any records exist obtained this shelter by appropriating for the purpose natural caves in the earth. He was, in fact, as regards his dwelling-place, on a level with the lower animals, such as the cave-bear and the cave-hyæna; he was a cave-man. Dim and uncertain as are the conditions of this primeval man and the country he lived in, they are only slightly less conjectural than those of the early inhabitants of this country prior to the invasion by the Romans. Certain it is, however, that in some rude and primitive fashion these ancient Britons made for themselves dwellings which were superior to those of the most barbarous nations. In very early times it seems to have been customary to surround the dwelling with a mud wall as a protection both against wild beasts and human enemies. Thus a second element, that of defence, was introduced. With the gradual growth of civilisation, dwellings began to assume a character more in accordance with decency and morals. Some rude magnificence was introduced into the houses of the nobles, and, besides the primary ideas of shelter and defence, thoughts of comfort and order began to assume prominence. The Norman Conquest flooded the island with warlike knights eager to be rewarded for their services with grants of the fair pasture-lands of England. They had their rewards, and through the length and breadth of the land strongly-fortified castles rose on every hand. A new prominence was thus given to the idea of defence, and this influenced to a very great extent the character of domestic architecture during the middle ages. Coming down to more recent times, the castle will be found giving place to the mansion, and, at the same time, with the decay of feudalism, a new class, that which is now called the middle class, comes into prominence with houses adapted to their special needs, and the development of the more purely homelike idea is commenced. What records exist of the social habits of the earliest times show that men's ideas of comfort and decency were of the barest possible kind. Although remains exist which prove that the Britons were in the habit of paving the floors of their dwellings with thin stone, yet there is no doubt that earth floors were common many centuries later than British times. As late as the thirteenth century the space below the dais in the hall is called "the marsh"—doubtless from its filthy condition. Probably, one of the earliest records of attention to sanitary matters is in the London Assize of 1189, where mention is made of "cameræ privatæ;" or privies, and from time to time in contemporary documents passages occur, relating to this and the kindred subject of drains to carry off foul water. Thus another element, that of health, is introduced.

These various elements, shelter, comfort, defence, order, and health, were expressed

in many different ways; but in most cases there is, over and above the bare necessities of the time, the addition, in a greater or less degree, of ornament.

It is, then, the combination of these elements with the addition of ornament which forms architecture.

Now the thought of health has an important bearing on all details of architecture, be they simply those which relate to the strength and permanence of a dwelling on the one hand, or those which tend to cultivate a refined, and therefore healthy sentiment in matters of taste on the other. For unless the house be well and strongly built, the health of the inmates will suffer from its defects, and unless the design be one which supplies all the requirements of good taste, the mind is apt to be prejudiced by its influence. Moreover, no design can be regarded as attaining to real excellence which does not insist, not only on that which delights the educated and refined eye, but on that which, in its form and in its composition, is conducive to the health and the comfort of those who are subjected to its influences.

The special conditions which have affected architecture in the past, and do affect it in the present, will now be dealt with; and it is purposed to endeavour to deduce from the consideration of these conditions some general principles of design, applicable to domestic architecture in this country at the present day.

But first, it may fitly be inquired, what in broad terms constitutes good architecture?

Palladio, quoting from Vitruvius, says: "that in every fabric three things are requisite, viz., *Conveniency*, *Strength*, and *Beauty*; for without them no building can merit our esteem and approbation."

"Architecture," says M. Viollet-le-Duc, "is composed of two elements—theory and practice. The theory comprises the art, properly so called; the rules suggested by taste, outcomes of traditions, and the science, which can be demonstrated by invariable absolute formulæ. The practice is the application of theory to needs; it is practice which accommodates the art and the science to the nature of the materials, to climate, to the manners of the age, and to the necessities of the time."*

Taking, then, the three heads of Vitruvius: under the head of Conveniency will be found, first, the obvious truth that every building must be appropriately arranged for the purpose for which it is to be used; and secondly, that not only must the parts be disposed in a convenient and seemly fashion, but the ornament and character of each kind of building should be distinctive and appropriate to the purposes for which the building is required. Thus, a church must be arranged with due regard to the mode of worship contemplated; a palace for ceremonies; and a dwelling to the habits and requirements of the inmates. So also the ornament that would be seemly and appropriate in a church would be misplaced in a theatre, and *vice versa*.

Again, in planning a house in which people are to live under circumstances of health, proper provision must be made for ventilation, for warmth, and for protection from climatic changes, and this provision must of necessity depend upon conditions special to the countries which these people inhabit.

The second requirement, Strength, is perhaps not the least important of the three. The various materials used in construction must each be appropriate to its

* "Dictionnaire Raisonné de l'Architecture," Vol. I.; Art. "Architecture."

peculiar purpose, and must be used with due regard to the laws which govern and control natural forces. Again, the supports of a building must be disposed in such a manner that no unnecessary expenditure of strength or material is involved. The best construction is that which combines the maximum of strength with such economy of material as is consistent with beauty of form.

The third head, Beauty, is divisible into three parts—harmony, proportion, and ornament. Though the subject is capable of further subdivision, yet, for the present purpose, it is sufficient to consider these three elements as together forming beauty in architecture.

Harmony may be defined as an effective blending of parts, often very diverse in themselves, into a rhythmic and consistent whole. It is, in fact, analogous to the harmony of music, which consists of an effective blending or combination of sounds of different pitch. Each sound or note is beautiful in itself, nor can it be said that any one note is more beautiful than another. Similarly, many forms used in architecture, as the circle, the square, the triangle, and so forth, have each their special fitness, nor can one form be said to be more valuable than another. But just as in music, the improper combination of notes produces an unpleasant sensation which is called discord, so in architecture the improper combination of parts produces an analogous effect, which may also fitly be called discord. Harmony in architecture is not alone a harmony of form; it is, perhaps, more closely connected with emotion. The vaulted roof and stately columns of a mediæval cathedral, which are the outcome and expression of a refined and lofty religious system, would clearly be out of tune with the requirements of a modern music-hall; on the other hand, it is quite possible for architecture of a style and period totally diverse to be placed side by side in the same building with perfect consistency when harmonised. Witness, for instance, the tombs of the Cardinals Amboise, in Rouen Cathedral, and the beautiful renaissance stalls in many of the Belgian cathedrals.

Again, harmony by no means implies a necessary uniformity. To illustrate the truth of this we have only to contrast such examples as the Rows at Chester, and the Spanish houses on the Quay at Ghent, with those in such a street as Gower Street, or in one of the rows of stuccoed mansions constantly springing up at south Kensington.

In the old examples, there is a variety and play of fancy applied to similar forms and for similar purposes, whilst in the modern work instanced above a dead level of uniformity is reached which can only be likened to a tune consisting of one phrase only, constantly repeated.

Proportion is a property essential to good architecture, and is closely allied to the previous one of harmony. Although proportion plays a most important part in architecture, yet it is, as has been well remarked, "difficult to say wherein it consists—as difficult as to say what beauty is, of which indeed it is one of the elements." Theories without number have been propounded to show that proportion consists of more or less intricate mathematical problems. We are told that mediæval cathedrals are developments of squares and triangles, or combinations of one or both of them amongst other systems. These theories, at least some of them, certainly work out logically enough; it is unfortunate, however, that in so many instances they follow, instead of preceding, the buildings to which they are applied. These theories of mathematical proportions in varied forms were at one time rigidly

applied in the planning of dwelling-houses. As might be expected, they were frequently antagonistic to convenience, and, as a result, the health and domestic comfort of the inhabitants were sacrificed to an idea.

It is the eye and hand, accustomed from tradition, tuition, and practice, which in each case seizes upon and determines those just and correct proportions which the mathematician afterwards reduces to rule by the aid of his science. Closely allied to, and, in fact, forming part of, the element of proportion is the principle of symmetry. At one period the desire for rigid symmetry carried architects to most extravagant excesses. If a wing were required on one side of a house to accommodate the stables, a corresponding wing was invariably provided to balance it, and this wing might, and often did, contain the chapel. The absurdity of such an arrangement will be apparent when it is recollected, apart from the objection that would exist in many minds to an association of idea between the stable and the chapel, how totally different the necessities of warming and ventilation in these buildings are, and yet for the purpose of symmetry, the convenience and health appliances of the one must be sacrificed to the appearance of the other, or both must suffer.

In one plan for a comparatively small house by Palladio, there are no less than four staircases, two of which are obviously planned to balance the other two. It will readily be seen that, carried to excess, this idea of symmetry involves inconveniences and absurdities in the internal arrangements of a house for which no amount of grandeur in the exterior can possibly compensate.

The third constituent of beauty, ornament, may be defined as the refinement or enrichment of a building by the application of carving in some form or other, of colour, or of other forms of decoration; the object in view being either an attractive appearance, or the amplification of the ideas suggested by the general forms. In whatever way it be applied, it has been held that ornament must be subject to two rules; first, it must be accessory to the design of which it is to form a part; secondly, it must be appropriate to and in harmony with the surroundings.

To this must now be added that the ornamental accessories of a house must, both as to form and material, be strictly in accordance with sound principles of healthy construction. Of ornament, beautiful in itself, but hopelessly misapplied, the caryatid porches at St. Pancras Church in the Euston Road are conspicuous examples.

It is not, moreover, by any means a rule that ornament is even necessary to good architecture. As Gwilt observes, "The absence of it altogether is in many cases a mode of decoration." Grecian Doric, for instance, is a style which may be used quite independently of ornament. So also in many of the domestic buildings of the Middle Ages true architectural effect is often obtained without the aid of ornament. Such examples as the warehouses at Nuremberg, and the public schools at Oxford (street front), evidence the truth of this; or, to cite a modern example, Newgate Prison is a building which, from the very fact of its rigid lack of ornament, satisfies the critical eye.

The danger accompanying the use of ornament is, that it is likely to become the mistress, and not the handmaid, of the architect, whose power is oftener shown in withholding ornament than in applying it.

Two kinds of ornament are at the service of the architect, form and colour

Under the head of form are included all kinds of mouldings and sculpture. Mouldings may be defined as the application of curved and recessed surfaces to constructional features. A moulding should always have the effect of appearing to strengthen the part to which it is applied by emphasising the main constructive lines. Theoretically, a moulding should be actually part of the essential construction; practically, it is generally an independent feature applied to the construction. The function of a moulding being to enrich the part to which it is applied by the addition of certain effects of light and shade, it may be conceded that, provided the result is subordinate to the main lines, the question of whether it is worked out of the solid or "stuck on" is of no great moment. In the term sculpture may be included, besides all kinds of carved ornament, the use of ornament cast or moulded in plaster, and of incised work. Except in such cases as sculpture of a monumental character, where the architecture serves only as a frame to the statue, sculpture should always be subordinate to the main lines of a building. It should serve to emphasise and enrich without being so conspicuous an object as to attract attention for itself. In the most perfect development of any style, whether it be Greek or Gothic, it will be found that the sculpture, exquisitely beautiful as it is, is invariably subordinated to the architecture. It may therefore be taken as an axiom that where the most striking and conspicuous part of a building is the carved ornament, there the ornament, good as it may be, is in excess and misapplied. At the same time it is perfectly possible for a building to be literally covered with ornament which yet is subordinated to the design of the whole. Instances of the truth of this may be seen in the Town Hall of Louvain, and among modern buildings, the Houses of Parliament at Westminster.

In the application of colour to the exterior of a building, regard must be had, first, to the amount of coloured materials available, and, secondly, to the probability of these materials permanently retaining their colours. The application of fresco painting to this purpose, as at Munich, in the Tyrol, and at Orvieto, is obviously unsuited to the climate of this country. Such coloured decoration as can be applied to the exterior of buildings ought, in this country, to have a washable surface. This is more especially necessary in towns where the atmosphere is loaded with deleterious gases. For ordinary purposes, stones of various colours, marbles, granites, and coloured bricks are readily available. Terra-cotta, glazed and unglazed, majolica, and encaustic tiles all lend themselves to external decoration. The application of glazed terra-cotta in various forms is a mode of decoration which does not seem to have had as yet the attention it deserves.

Probably, now that conditions relating to health are more held in view than formerly, the very great advantages which necessarily follow from the adoption of surfaces which can be washed will lead to a further development of this mode of decoration. Marble inlay and glass mosaic both present facilities for decoration of a more elaborate nature. It rests with the architect to make choice of such materials as will best harmonise and endure.

The conditions which affect domestic architecture are principally climate, materials, and social habits.

The climate of a country has necessarily a very important influence on the form and construction of the dwellings of its inhabitants. In this country we have not

the extreme variations of temperature prevalent in countries of different physical conditions. There are, however, even in the mild and equable climate of England, considerable variations in the amount of rainfall in different parts, the mean annual rainfall varying from under 25 inches in the eastern counties to as much as 165 inches at Seathwaite, in Cumberland. Thus it becomes necessary in many localities to take extra precautions to keep out the rain. It is this equable climate which gives their distinctive character to English houses as compared with houses in Italy and Spain, where a main thought is exclusion of excess of light and heat; or in Russia, where double windows and extra thick walls are needed to afford protection from cold.

Of equal importance to the present purpose is the subject of materials.

The range of materials readily at hand and fit for use has always exercised a very distinct influence on the architecture of the country. In ancient Greece the temples which have remained for some twenty-five centuries as monuments of the skill and genius of their designers evidence the influence which the possession of an enduring and beautiful material had upon forms derived from construction in timber. Again, in two such widely-separated countries as Norway and China, the use of wood has had the effect of producing churches in the former curiously resembling the pagodas of the latter.

In England, where in many parts stone is not indigenous, and is only to be procured at great cost for labour and transit, the material most largely used for walls is brick. It follows, therefore, that the use of brick has in many places greatly modified the architecture of the country. Indeed, it may be affirmed that the use of brick has produced at least one distinct style of architecture in this country. The brick architecture of the seventeenth and eighteenth centuries, which it is the fashion now to call Queen Anne, was certainly, amongst other causes, developed by the thoughtful and judicious application of brickwork to domestic building, and doubtless was in no slight degree due to the lesson derived from the great fire of London.

It will generally be found the safest and most economical plan to utilise such materials as may be at hand. Curious mistakes in this direction have been made for want of a little technical knowledge on the part of the designers. Thus, in building the Government House at Corfu, a soft and perishable limestone was transported from Malta, Corfu itself possessing a far superior stone for the purpose. A like blunder was made at St. John's, Newfoundland, where granite was brought from Aberdeen for building the Government House, granite itself forming the ground hard by.*

* Prof. Rupert Jones's Annual Address to the Geological Association, 1879.

CHAPTER XXVI.

EARLY HISTORY OF ARCHITECTURE.

Influence of Social Habits on Architecture—The Feudal System—Early Neglect of Sanitary Conditions—Gradual Improvements—Rise of successive Styles of Domestic Architecture—Effects of increased Civilisation and Refinement.

THE influence of social habits and manners is perhaps the most important in its effects on domestic architecture of any that have yet been mentioned. It is an influence that is always at work, and in the present day is largely taking the line of improved sanitary arrangements; a part only, but a most important part of the comparatively new but important science called Social.

The progress of architecture in its artistic aspect is so closely bound up with social progress that the two may fitly be considered simultaneously. In order to do this it will be necessary to treat the subject to a certain extent historically.

At the period immediately following the Norman Conquest, which is sufficiently early for the present purpose, it will be found that society in this country may roughly be divided into four classes—the nobles and small landowners, the clergy, the townsfolk, and the agricultural classes.

Following the custom then prevalent over the greater part of Europe, the Norman barons held the estates granted to them—and of course in many cases seized by main force from their Saxon owners—in fee from the Crown, the fee being military service. The great feudatories commonly divided their estates somewhat in this manner:—A portion would be granted to one or more tenants in consideration of certain services being performed. These tenants were freemen, and their tenure was what is now called freehold. The portion reserved for the lord's own residence was called the demesne, and of this a threefold division was frequently made by him. One part he retained in his own occupation, to be cultivated by his villeins, or bondsmen, for his own sustenance; of another part, he delivered possession to the villeins themselves for their sustenance, who in course of time became copyhold tenants; the third part was termed the lord's wastes, and served for roads, and for the enjoyment of the various rights of common for himself and all the tenants.* In the lawless and unsettled state of society it became necessary for every man who had the means of defence at his command to construct his dwelling in such a manner that it would stand a lengthened siege. The Normans knew well how to do this, and hence it is that such valuable records of their times remain in the numerous castles which exist to this day. Of castles belonging to this period the following may be cited:—Tower of London, Rochester, Dover, Colchester, Norwich, Guildford, Oxford, Bamborough, Corfe, Conisburgh, York, Tunbridge. Cromwell's soldiers did their utmost to destroy Corfe Castle, but only succeeded in detaching huge masses of masonry, which still remain on the side of the hill where the soldiers left them.

The castle usually consisted of a square or round tower, called the keep, in

* "Sussex Archæological Collections," Vol. XXI., p. 116. The statute "Quia emptores," prohibiting sub-infeudations, was passed in A.D. 1290. All existing manors date, therefore, from before that time.

which were placed the living-rooms of the owners. These rooms consisted usually of the hall, or common room, where every one fed, and where the visitors, retainers, and servants all slept. An upper room served as a bed-room for the lord and his family. Under the whole was the dungeon. The domestic offices were generally little better than sheds of wood, built in the courtyard. The roof of the keep was usually flat, and the parapet walls were pierced by crenells, or battlements, to construct which a royal licence was required. The courtyard, or ballium, was enclosed by walls of great thickness, which were also crenellated, and frequently furnished with towers for the purpose of defence. Around the whole was a fosse, or moat. Some idea of the amount of castle-building which went on in the period immediately following the Conquest may be gathered from the fact that, in the reign of Stephen, upwards of 1,100 castles existed within the boundaries of England.

The smaller class of landowners, the sub-feudatories, frequently had their houses constructed of wood, and in cases of danger most probably took refuge within the precincts of the castle of the over lord. Sometimes, however, these manor houses (as was the case more frequently in later times), were constructed of stone, and of sufficient strength to withstand assault. They rarely contained more than two rooms, probably never more than three.

The condition of the villeins was wretched in the extreme, in fact, scarcely better than slavery. Their dwellings were commonly rude hovels of mud and thatch, in the one apartment of which the whole family slept. Sometimes two apartments existed, one of which was allotted to the cow. The floors were either of mud or roughly paved with pebbles.

The towns resisted successfully all encroachments of feudalism, and preserved their independence, although subjected at times to considerable hardships at the hands of the nobility. Owing to the almost universal use of timber, very few remains of domestic buildings in towns prior to the thirteenth century exist. The house called the Jew's House, at Lincoln, is a tolerably well preserved specimen of the period. The doorway and the two window-openings on the upper floor are characteristic examples of Norman work. The house appears to have consisted of two rooms only, one on the upper and one on the ground floor, though it is possible that one or both may have been divided by internal partitions.

As a rule, however, houses in towns were principally built of timber. Thus we find that in order to remedy, if possible, the inconvenience and loss occasioned by the constant occurrence of fires, the citizens of London, in the reign of Richard I., framed certain regulations touching the construction of houses, which are embodied in a document bearing date 1189, and called "An Assize." This interesting record, the first "Building Act," recites that in ancient times, that is, prior to the year 1189, "the greater part of the city was built of wood, the houses being roofed with straw, reeds, and similar materials. The frequent fires which took place owing to this mode of building, and more particularly the great conflagration in the first year of the reign of Stephen, which spread from London Bridge to the church of St. Clement Danes, destroying in its progress the cathedral, compelled the citizens to adopt some measures to avert the recurrence of such a calamity. "Therefore," says the Assize, "many citizens, to avoid such danger, built according to their means, on their ground, a stone house covered

and protected by thick tiles against the fury of fire, whereby it often happened that when a fire arose in the city and burnt many edifices and had reached such a house, not being able to injure it, it there became extinguished, so that many neighbours' houses were wholly saved from fire by that house."*

It will be seen from the foregoing extract, that little or no advance had been made in the mode of building since Saxon times. The "Assize" commences by laying down rules for the formation of what we now call party walls. These walls were to be of stone and three feet thick; the height was to be sixteen feet, which seems to imply either that the upper storey was formed partly in the roof, or that a superstructure of timber was contemplated. Certain privileges were granted to those who adopted the plan of building walls in this manner. The Assize did not, however, have the result of making London much more secure against fire than it had been. In the year 1212 a great fire took place, which destroyed London Bridge and a great number of houses besides. Upon this the citizens promulgated a fresh set of decrees, which show how little the former ones had been productive of lasting results.

Both the Assize of 1189 and that of 1212 incidentally furnish us with much valuable information as to the materials in general use. Thus we learn that the outsides of the houses, which in former times had been covered with reeds or rushes, were now frequently plastered, as also were the insides. Tiles, wooden shingles, and lead, are mentioned as roof-coverings.

Windows, when not mere holes or slits in the wall, were furnished with wooden shutters, sometimes double; oiled paper and canvas stretched on frames also served the purpose for which glass was in later times substituted. For further protection the lower windows of houses were frequently furnished with strong iron gratings or grilles.

Chimneys were certainly in use during the twelfth century, as for instance, at Rochester Castle; but their use was probably confined to the more private rooms of castles where the great thickness of the walls lent itself readily to the arrangement.

The great hall, which was a feature which existed in the houses of the Saxon Thane, and of which a record still exists in the name "Hall" as applied to a country house, was the principal apartment of the castle or house, and on it was lavished all the ornament and refinement at the command of the owner. It served for banquets, for the dispensing of justice, for festivities by day, and for a sleeping-place for guests and retainers by night. The floor was frequently of earth, and strewn with rushes or straw. When it is considered that refuse from the table was, as a matter of course, thrown on to the floor; that dogs, hawks, and other domestic animals lived in the hall, it will scarcely be wondered at that the state of the floor became highly offensive. It is related as an instance of the extreme refinement of Thomas Becket, that he ordered his floors to be covered with fresh straw in winter, and in summer with fresh rushes, in order that such of his guests as could not find room at the tables might not get their fine clothes soiled by sitting on a dirty floor.

Besides the great hall there was an apartment called the solar (a term which

* "Some Account of Domestic Architecture in England," by J. Hudson Turner. From this valuable work, continued by Mr. J. H. Parker, C.B., we have drawn much of our information on this subject.

originally meant a flat house-top, terrace, or other part of a dwelling exposed to tho sun), which served as sleeping-apartment and parlour for the mistress. In many houscs this was the only apartment which existed specially set apart for sleeping. The guests had bags of straw or benches allotted to them in the hall, and the servants slept on the floor.

Under the solar a cellar was usually constructed, and was probably used for purposes of storage. The kitchens and other outhouses were for a long time mere temporary erections. In the reign of Henry III. (1216—1273) the royal kitchens at Oxford were blown down by a strong wind. When the king moved from one house to another orders were sent on in advance to construct such offices as would be required during his sojourn. This state of things continued until, with more settled times and more refined customs, it ceased to be the habit of a great baron to take his whole culinary department with him when he moved from place to place, and it became necessary to provide more permanent accommodation for the kitchen department.

What little is known about the sanitary arrangements of these early times shows how primitive and how unwholesome these arrangements must have been. In the London Assize of 1189 mention is made of "cameræ privatæ," and certain rules are laid down for their construction, and the distance to be preserved between those belonging to adjoining houses.

The sanitary arrangements of great religious houses were, however, if that of the monastery attached to Canterbury Cathedral may be taken as a fair sample, on the whole complete. The supply of water was obtained from a source outside the city walls, and conducted through a circular conduit-house by pipes to the precincts. Immediately outside the conduit-house there was fixed a circular pierced plate, the object of which was to intercept the larger impurities. Between this and the monastery precincts were five oblong reservoirs or settling tanks, through each of which the water had to pass. Inside the walls the water was conveyed in succession through a series of tanks in different parts of the monastery, and each one lower than the preceding one, the communication from one tank to the other being by pipes fixed underground. The last tank of the series discharged its overflow into the sewers of the monastery, and from this tank pipes conveyed the water to various parts of the buildings to supply the piscinæ, lavatories, etc. From each supply-pipe to a tank a short piece of pipe was branched and fitted with a stop-cock in close proximity to the nearest drain. The object of this pipe (which was called a "purgatorium,") was to let off the water from the pipe in order to cleanse it.

The privies of the monastery were arranged in a long hall, under which and against the outer wall ran a fosse, or open sewer. The hall was divided into compartments, which were immediately over the fosse. Into this fosse the waste water from the tanks and the whole of the rain-water from the roofs were turned, thus providing what must have been, except in seasons of drought, a constant flush throughout the sewer. This "necessarium" was also called the "third dormitory," which is considered by Professor Willis* to have been a cant name for cameræ privatæ.

* "The name is probably a cant one, perhaps derived from the habit of dozing in the recesses of this apartment, which may be inferred from one of the duties assigned by Lanfranc to the circa, or watchman, namely, to examine all the sedilia at night, lest any monk should be asleep there, in which case

In castles these privy chambers were frequently arranged in the towers or in projecting turrets, whence their contents were discharged into the moat. In the Liberate Rolls of Henry III., from which large extracts were made and translated by Mr. Hudson Turner, in his work on the Domestic Architecture of the Middle Ages, directions are frequently given respecting such chambers and drains. Thus on one occasion a privy chamber in the Tower of London is stated to be in "an undue and improper place, wherefore it smells badly," and Edward Fitz-Otho, the king's architect, is thereupon enjoined to erect another in such more fitting and proper place as he may select, "even though it should cost a hundred pounds."*

Again, an open drain or channel ran through the halls of the king's palace at Westminster, into which the refuse of the kitchens were discharged. To obviate the nuisance arising from this, an order was given to make "a certain conduit through which the refuse of the king's kitchen at Westminster flows into the Thames; which conduit the king ordered to be made on account of the stink of the dirty water which was carried through his halls, which was wont to affect the health of the people frequenting the same halls." †

If the great nobles, and even the sovereign, were content with arrangements of so imperfect a kind, it may fairly be assumed that the houses of the lower classes were infinitely worse, and it is possible to comprehend the fearful ravages which under such conditions were made by the plagues and pestilences of the Middle Ages. The filthy and undrained streets of the towns, down the centre of which in open channels the filth and refuse from the houses pursued its course to the river or stream, coupled with the absolute want of anything approaching ordinary personal cleanliness, must have rendered the inhabitants an easy prey to fevers, and that scourge of the Middle Ages, leprosy. It is said that in the black death of 1348, more than one-half the population of England was swept away.

The reign of Henry III., occupying fifty-seven years of the thirteenth century, was fertile, not only in amount but in improvement in domestic architecture. The king himself was an enlightened patron and student of the art. It was, moreover, during this century that the development of the first period of Gothic architecture, called early English, or First Pointed, reached its highest point. Salisbury Cathedral, the choir and transepts of Westminster Abbey, the presbytery of Lincoln Cathedral, and the chapel of the nine altars in Durham Cathedral, are a few of the well-known and beautiful works of this period.

The arrangement of hall and solar continued through this and the succeeding centuries; but in the case of castles, these apartments, together with the domestic offices, were frequently arranged within the inner ballium, or bailey, and independently of the keep, which was reserved for purposes of defence. The hall of Stokesay Castle, Shropshire, erected at the end of the thirteenth century, is a well-preserved and beautiful specimen of the domestic architecture of the period. Its dimensions are 51 feet long by 36 feet wide. The roof is of oak, and open to the ridge, the principals being curved and supported on corbels projecting from the wall. It is lighted by eight large two-light windows, divided horizontally by transomes, the

he is enjoined not to disturb the sleeper rudely by touching him, but quietly to make some little noise or stir that may rouse him."—The Architectural History of the Conventual Buildings of the Monastery of Christ Church in Canterbury, by the Rev. Robert Willis, 1869.

* Close Rolls, 30 Henry III. † Liberate Rolls, 44 Henry III.

upper lights having cusped lancets with plain circles in the heads. Inside the windows are carried down within a short distance of the floor, and each is furnished with two seats.

Manor-houses increased both in number and importance during the thirteenth century. They were frequently fortified, and provided with a drawbridge and moat. The arrangements of such houses were simple, but, as in the example given, appropriate to their purpose.

But little improvement can be traced in the architecture of either town houses or cottages of this period. This is probably due to the fact that timber was still so largely used for both purposes.

In the interiors of houses one of the most noticeable features was the window-seat. Glass was first used in domestic work in this century. It was a costly luxury for two reasons—first, because, having to be imported from abroad, the risk of fracture was greater than when it was made at home; and secondly, because skilled workmen were rare, and consequently expensive. In the following century the scarcity both of glass and glaziers is instanced by the fact that when the windows of the chapel at Stamford, founded in honour of Joan, mother of Richard II., were in need of repair, a writ was issued, empowering one Nicholas Hoppewell to take as much glass as he could find in the counties of Norfolk, Northampton, Leicester, and Lincoln, and to impress as many glaziers as should be requisite for the work.* Instances are not uncommon of windows which had glass in the upper part, but wooden shutters in the lower part.

As a covering to the walls of halls, wainscoting appears to have been a not uncommon feature. Frequent mention is made of wainscoting in the Liberate and Close Rolls of Henry III. before referred to, and orders are given to paint the wainscot of a green colour with gold stars, or to paint histories, figures of saints, and so forth.

Chimneys are frequently mentioned in the State documents of Henry III. It is not, however, until the succeeding century that they appear with any prominence as ornamental features.

The state of the floor of the hall in most great houses must still have been very unwholesome, as may be inferred from the fact that the usual name for that part of the hall below the dais was the marsh. Wood flooring was used to a great extent in the royal houses, and, it may therefore be fairly inferred, was also in use in the castles of the nobility.

The general use of whitewash, as applied to the exteriors of houses of all kinds, is a noteworthy feature of this period. So highly was it esteemed, that the citizens of London protested against the use of "sea-coal," on account of its tendency to blacken their whitewashed walls. Whitewash was also applied to thatch as a preventive against fire. This custom still prevails in parts of Wales. An order occurs in the Liberate Rolls, before referred to, to construct pipes to convey the water from the leaden gutters of the great tower down to the ground, "so that the wall of the same tower, which has been newly whitewashed, may be in no wise injured by the dropping of rain-water, nor be easily weakened." †

Rude and imperfect as the water-supply of most towns continued to be for many centuries, it would appear that London was in this respect in advance of the time.

* Hudson Turner's "Domestic Architecture." † Lib. Roll, 25 Hen. III.

It was in the thirteenth century that the first conduit for the supply of water was established at Tyburn, whence leaden pipes conveyed the water to the City. The pipes were laid in 1236. In 1285 the great conduit of lead was erected.*

The use of baths was first introduced towards the end of this century, probably from the East.

The fourteenth century marks roughly the period known as geometrical, or decorated, a period distinguished by the great beauty and perfection to which the development of window-tracery was carried.

Whilst the same general arrangements prevailed in castles and manor-houses as in the last century, the dimensions and number of apartments were enlarged, and the scale of magnificence greatly increased.

The hall, of which that at Penshurst is a good example of the period, became a noble apartment, with its gallery for minstrels at one end, and a recessed bay window, in which the buffet was placed. The characteristic windows with seats still appeared as the usual form of window in the halls.

In the fourteenth century a change of a notable character first began to make itself known. This was the withdrawal of the lord from the revelries of the hall into a parlour or withdrawing-room at one end of the hall, and whence he could look on at what was going forward without actually participating.

This really is the first notice of the coming change in manners, which resulted in the disuse of the hall for its original purpose.

Although the halls of this period and even later were usually unprovided with chimneys, and the smoke from the brazier or andiron in the centre of the floor was allowed to find its way out through a louvred turret in the roof, the chambers generally had fireplaces and chimneys. The chimneys were designed with care, and were often remarkably picturesque features.

The number of privy chambers too was remarkable. It seems to have been thought a matter of necessity to provide one for each room. Frequently a tower was set apart for the purpose, called the garde-robe tower.

In this century the domestic offices assumed a more permanent character, and were often of a very extensive nature. The kitchen especially was frequently a spacious and lofty apartment, not uncommonly with a vaulted stone roof, in the centre of which was a lantern-light.

The intelligent interest taken by Edward I. in the arrangement of towns exercised an influence, which in several instances has lasted to this day. The free towns (Villeneuve and Villefranche), which he founded in Guienne and Aquitaine, were laid out with a scientific regard to sanitary conditions which is remarkable, and was certainly far in advance of the thought of the age. The principle upon which these towns were planned was similar to that of a modern American town. The market-place formed the centre, from which the streets diverged all at right angles. The streets were broad and spacious, and though the space was utilised to the best advantage, ample provision was made for free access of light and air. Special privileges were granted to these towns to encourage the people to flock to them; their influence on the civilisation and moral progress of the people can hardly be overrated. Added to this was the further important fact that these free towns were one great means which the king had of counter-

* Roberts's "Social History of the Southern Counties," 1856.

balancing the power of the barons. This end was largely advanced by the opportunities for the development of commerce and the arts of peace afforded by the municipal privileges of these towns.

With the beginning of the fifteenth century, the period of the Perpendicular style of architecture, the strongly-fortified castle gave way to the mansion in which the idea of the dwelling gained increasing prominence. Architecture as applied to dwelling-houses assumed at this period a more purely distinctive and domestic character. The idea of fortification did not, however, disappear in an abrupt manner, but for some little time the two overlapped as it were, and houses built as ordinary dwellings still retained features of the castle in the shape of crenellated parapets, loopholes, and portcullises. The introduction of gunpowder (first used in battle by the English at the battle of Crecy, 1346), had rendered the old method of fortification comparatively useless as a protection against the attacks of artillery. The transition from the old to the new order of things is well illustrated by the remains of Hurstmonceux Castle in Sussex, where the spacious and unprotected windows of the later period are in close juxtaposition to the crenells, the loop-holes, and the drawbridge of the older time. This house was built in 1422 to 1471 by Sir Roger de Fiennes, an Agincourt veteran, who obtained the licence to crenellate in 1440. It is also interesting from the fact that it is probably one of the largest brick buildings of the period.

Little change of plan took place with regard to the great hall, which still retained its prominence. In details of decoration and furniture, however, great progress was made; it was the age of the magnificent open timber roofs of Eltham Palace and Westminster Hall. During this period, too, woodwork of all kinds, but especially in wall panelling, was carried to a most sumptuous and beautiful point of perfection. Glass appears to have been more generally employed, and it was during this century that the manufacture of glass was first carried on in England. Dwellings in towns, with the increasing wealth and importance of the townsfolk, were of increased dimensions. They were and continued to be very frequently of half-timber work, but several remains exist to show that considerable care and skill was expended in their design. The storeys usually projected one over the other, and were carried on richly carved or moulded brackets.

From the description of the construction and arrangement of the city of Troy in a MS. of the fifteenth century—Lydgate's "Siege of Troy"—which may be taken as describing generally a contemporary English town, it would appear that considerable progress had been made in sanitary matters.

After describing the character of the masonry and other matters of interest, amongst which may be mentioned covered ways, or "deambulatories," in which the citizens might walk sheltered from the weather, the writer proceeds to describe the methods of disposing of refuse :—

> "And eūy * hous cūred † was with led
> And many gargoyl and many hidous hed
> Wt spoutis thorugh, and pipes as yei ought
> Ffrō ye ston werke to ye canel raughte

* Every. † Covered.

Voydyng fylthes lowe into ye gronde,
Thorugh grates percid of yrē * percid roude
Yo stretis paued bothe in lengthe and brede
In cheker wyse with stonys white and rede."

The river which ran though the midst of the town is then described, and the "condut pipis" which conveyed "al odure and fylthes" to the river. The method by which these pipes conveyed away the filth, and at the same time washed the streets, was arranged in so crafty a manner that no man could tell where it all went to.

"Ffor ye canel skoured was so clene
And denoyded in so fell wyse,
Yat no man might espien nor denyse
By what engyn yo fylthes fer nor ner
Wer born away by cours of ye riuer
So couertly eury thing was cūred; †
Where by ye ton was outterly assured
Ffrom endengeryngo of al corrupcion,
Ffrom wikked eyr & from infeccion
That causyn ofte by her violence
Mortalitie and gret pestilence."

In the matter of water-supply some progress appears to have been made, and may fairly be assumed to have had some influence on personal cleanliness. An additional supply appears to have been brought into London, in 1483, by pipes from Highbury. The city of Leicester was in the fourteenth century still supplied by wells only, as appears by an order of the corporation, that no woman ‡ should wash clothes or other corruption in the public wells. That personal cleanliness was certainly thought of at this period with special reference to health appears from the following extract from a manuscript translation of "Palladius on Husbandrie," preserved in Colchester Castle, the date of which is about 1420:—

"It is not strange, if water wol suffice,
An husbonde on his baathe to be bethoughte;
For thereof may pleasaunce and *helthe* aryse.
Towarde the sonne on drie it must be wrought,
Southwest and southe the sonnes ynne be brought,
That alle the day it may be warme and light."

Minute instructions follow for constructing the furnace, floor, supply of hot and cold water, and of the bath itself. In another part of the same manuscript advice is given about choosing a supply of water and a site for the house. The construction and arrangement of the house itself is also described; but the book being by an Italian, these details are scarcely illustrative of buildings in England.

The evils resulting from the pollution of rivers by the excrement and other refuse of towns being allowed to drain or be cast into them was recognised in a proclamation of Edward IV., enjoining the execution of various statutes directed against the custom.§

* Iron. † Covered. ‡ Roberts's "Social History of the Southern Counties," 1856.
§ Roberts's "Social History of the Southern Counties," 1856.

Domestic architecture, as before remarked, assumed in the fifteenth century a more purely distinctive character, which became the groundwork of the styles of the succeeding century, and, in fact, retained its influence well into the seventeenth century. The most marked feature is the window. The openings were divided by mullions and transoms into several lights; often there were three in height, one above the other, and windows, five and six lights in width, are by no means uncommon. The bay window became a frequent feature, and was often semicircular in plan. The heads of windows are almost invariably square, the cusping, or pointed heads, being subordinated to the lintel over the whole. The growing custom of the lord abandoning the hall as his living-room for the "privy parlour with chimney," denounced in "Piers the Plowman's Creed," is illustrated by the great beauty and richness displayed in the chimney-pieces.

With the end of the fifteenth century a period of great social and political change begins. The first of these changes, the decay of feudalism, had been the gradual work of centuries, which culminated with the fusion of the houses of York and Lancaster in the accession of Henry VII. Perhaps the most notable of the results of this social change was the rise of two important classes of society into prominence. These were the class of landowners ranking next to the great feudal barons, and who may be called the country gentlemen, and the wealthy and influential citizens of the great towns, with their guilds and chartered privileges, generally extorted from the king as payment for large subsidies.

The next important change is the suppression of the religious houses, which, whatever may have been the motive, and however arbitrary and oppressive were the methods of carrying it into execution, undoubtedly was a measure the good effects of which can hardly be over-estimated.

The most momentous change of all, however, was the introduction of what is called the new learning. The great wave of intellectual revival which had its starting-point in Florence, and which, in course of time, influenced and directed not only literary studies but the arts of design and the customs of domestic life, first reached England at the end of the fifteenth century. And although it was not until the seventeenth century that the architecture of the Renaissance was fairly established in this country, yet the intellectual and moral effects of the movement can clearly be traced in the improved habits and morals of the people.

This improvement extended to all classes of the community, except, perhaps, to the agricultural labourer, who, even to this day, is, in some parts of England, scarcely better housed than his predecessor of the Middle Ages.

Farm-houses of "wattle and dab" in many instances gave place to the substantial stone buildings, some of which remain to this day. In some parts of the country cottages exist built of stone, and evidencing in their quiet picturesqueness the capabilities of the style to the smallest classes of houses. A row of cottages at Glossop, many of which have been scarcely altered since their erection, show in their mullioned windows the adaptation to the humblest needs of architectural features used in the largest mansions.

As a specimen of the smaller class of manor-house, that in the same village is a characteristic example.

The inventories and wills of the period show how greatly the furniture and utensils of the households of people of the yeoman class had improved. Pewter and

even silver were substituted for the wooden trenchers of earlier times; and carpets occasionally took the place of the filthy rushes or straw on the floors. The lofty and substantial houses of the wealthier burghers, often fitted up with costly panelling and valuable furniture, mark the rise of the great middle class which has had so important a part to play in subsequent history. The development of commerce and manufacture had, however, a tendency to foster the growth of large towns, which in those days of imperfect sanitary knowledge led to serious results in the cases of epidemics. Thus the Black Assizes at Oxford are clearly traceable to the overcrowded and unwholesome state of the city. Erasmus writing to Franciscus, Cardinal Wolsey's physician, attributes the sweating sickness and the plague, from which England was hardly ever free, to the incommodious form and bad arrangement of the houses, the filthiness of the streets, and the dirt and disorder within doors.

In the year 1601, the 43rd of Elizabeth's reign, an Act was passed which consolidated and improved upon some former Acts, and became the basis of the system of Poor Law relief and administration until recent times. This legislation undoubtedly had a most important bearing upon the social and moral condition of the poorer classes. The gangs of idle and worthless vagrants were compelled to labour for their sustenance, while the duty of providing for the aged and infirm paupers devolved upon the parishes, and rates were levied for both purposes. Compared with the legislation of previous times which reduced labourers to the condition of serfs, who were bound to the land upon which they worked, and when beggars were hanged by fifty at a time, this was indeed a step in advance.* Nor was this the only direction in which the social condition of the labouring classes received an impulse in the direction of improvement. Farming and manufactures began to be developed and improved, and, as a natural consequence, the demand for skilled and unskilled labour increased greatly. In Elizabeth's reign, too, the first beginnings of that career of commerce and navigation for which this country has ever since been so pre-eminent were made. The foundation of the Royal Exchange by Sir Thomas Gresham in 1556 is a notable landmark of the progress of the commerce of the period. With all this commercial, agricultural, and manufacturing activity, fostered by the wise and frugal care of the sovereign, aided by a council of ministers of no common order, the social change was naturally very marked.

The houses of the nobility and wealthy gentry assumed a character altogether different from that of feudal times. The long galleries, the projecting oriels and bay windows, the broad terraces and stately flights of steps, mark a new departure in domestic architecture. The lavish use of glass, against which Lord Bacon enters a protest when he remarks that "you shall have sometimes your houses so full of glass that one cannot tell where to become to be out of the sun or the cold," was a feature in houses of this period which could not fail to have an important influence for good on the health of the inmates. Still, it is curious to find amidst all the lavish expenditure in household and personal adornments which characterise the age, the old custom of strewing the floors with rushes or straw still to a great extent kept up. The use of carpets, except on extraordinary occasions, was indeed considered a mark of extreme luxury and foppishness.

* Hallam's "History of the Middle Ages."

CHAPTER XXVII.

ARCHITECTURE FROM THE SIXTEENTH TO THE EIGHTEENTH CENTURIES.

Tudor and Elizabethan—John Thorpe—Inigo Jones and the Classic Style—Its Faults—Rebuilding of the Metropolis—Sanitary Condition of the Great Towns—Principal Architects of the Eighteenth Century.

ARCHITECTURE in the sixteenth century may be divided into two periods, the Tudor and the Elizabethan; the former of which may be regarded as the latest phase of Gothic, whilst the latter is the earliest phase of Renaissance—more properly, perhaps, the transition from Gothic to Renaissance.

Of Tudor architecture, Hengrave Hall, in Suffolk, is a beautiful and fairly complete example. It was begun by Sir Thomas Kitson in 1525, and completed in 1538. By alterations in the seventeenth and eighteenth centuries the house was reduced to one-third of its original size. A complete inventory of all the rooms and their contents as they were in 1603 exists, however, and affords a most interesting insight into the arrangement and furniture of a nobleman's mansion of the period. From this it appears that several of the chambers were arranged in suites of three or four rooms each. It is also recorded that separate chambers were allotted to the nursery, the bath-room, and the linen-chamber. There were two still-rooms, a laundry-house, pastry-room, wet and dry larders, "fyshe-house," dairy, cheese-chamber, and various rooms pertaining to the brewhouse and stable. There was also a slaughter-house. The great hall was a noble apartment with a music-gallery at one end. A room was set apart for the musicians, and a list of their instruments is given in the inventory of "necessaries."

The principal rooms were arranged around an inner quadrangle, and the hall was on that side of the quadrangle opposite to the principal entrance. A corridor, running round the sides of this central court, afforded access to the several rooms, an arrangement which was afterwards developed by Thorpe to a considerable degree of elaboration.

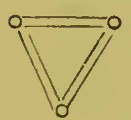
The most noticeable features of the main entrance front are the four octagonal turrets, the two flanking the entrance-porch being crocketed and similar in form to those of Henry VII.'s chapel at Westminster, and the projecting window over the porch. All the windows have the flattened arch peculiar to the later phases of the Perpendicular period, and the embattled parapet marks the still lingering features of the castle.

An important feature in all large houses of this period is the gallery; of this the one at Hatfield, though possibly belonging rather to the commencement of the next century, is a good example. The well-known galleries at Knole and Haddon Hall belong to this period.

Before proceeding to describe the second or Elizabethan period of architecture, it will be well to note the remarkable development of timber construction in this century. Many large mansions were erected almost wholly of timber framing, with the interstices filled in with plaster. This kind of building was extensively practised in the north, Cheshire and Lancashire being peculiarly rich in remains of the kind. Moreton Hall, Speke Hall, and Bramhall Hall are examples, amongst many

others, of the degree of picturesque beauty attained in this manner. Remains also exist to show that the same forms and construction were employed in town houses.

As before said, the second or Elizabethan period was a link between the Gothic of the past and the classic of the future. The Gothic influence is shown in the retention of the stone mullions and transoms, and the gabled roofs with other minor features. The influence of Italian art is shown principally by the application, in more or less debased forms, of the classic orders, and the substitution of balustrades for battlemented parapets. A curious and interesting volume is preserved in Sir John Soane's Museum of plans and views of houses designed by John Thorpe, an architect who lived in the latter end of the sixteenth century, but of whom unfortunately absolutely nothing is known beyond the fact that he made the drawings referred to. The volume contains plans, amongst others of Buckhurst Hall, Kent; Woolaton Hall, Nottinghamshire, 1580–88; Burleigh, Northamptonshire, 1575–80; Holland House, at Kensington, 1606–7; Audley End, Essex, 1610–16; Longford Castle, Wiltshire, 1591; and Holdenby House, Northamptonshire, 1580. The plan of Longford House is a curious device; it is founded on a diagram of the Trinity, the principal rooms being in the circular corners, and the offices and corridors in the connecting bands. There is also an ingenious and quaint plan for a house for himself, formed of the two initial letters of his names, I and T, joined by a band. The T contains the living-rooms and the I the domestic offices.



It is curious to note that in many of Thorpe's plans an endeavour is made to provide each bed-room with a privy. The increase in number and in the size of the servants' apartments is also noticeable.

It was not until the earlier part of the seventeenth century that the forms of classic art were fairly established in this country; and even then Elizabethan details continued to be not unfrequently employed; indeed, in some parts of England these details have been continuously employed until quite recent times.

The employment of classic forms in architecture was part of the results of the Renaissance or revival of learning referred to above. It took some time before it was freely adopted here, but once established it took firm root, and became the one accepted style for nearly two centuries.

The essential difference between Gothic and classic art is that whilst in the former the window is the most characteristic feature, and the one by which the period of a building can almost invariably be decided, in the latter the columns, with their appropriate cornices and bases, are the dominant members. In classic art the five orders, with their rigid and inflexible rules, govern and control the whole design. Some idea of the importance attached to the classic orders may be gathered from the following extract from "A Parallel of the Ancient Architecture with the Modern," by Roland Freart, Sieur de Chambray, published in Paris in 1650, and "Made English for the Benefit of Builders," by John Evelyn in 1664. After giving his reasons for discarding the Tuscan and composite orders, the author goes on to describe the other three as "the very flower and perfection of the orders, since they not only contain whatsoever is excellent, but likewise all that is necessary of architecture." The loss of the first principles of the art is thus accounted for:—"So many ages of ignorance have passed over us, especially in the

arts of architecture and painting, which the war and frequent inundations of barbarians had almost extinguished in the very country of their originals; and which were in a manner new born again but a few years since, when those great modern masters, Michael Angelo and Raphael, did, as it were, raise them from the sepulchres of their ancient ruins, under which these poor sciences lay buried." One of the earliest instances of the use of the "orders" in this country is the beautiful "Gate of Honour," at Caius College, Cambridge (1565 to 1574).

With the establishment of classic architecture a period is reached when the individual architect comes into prominence, and it is possible to judge of him not only by his executed works, but by his unexecuted projects.

To Inigo Jones unquestionably belongs the credit of having first brought to perfection in this country the classic, or, as it may conveniently be called, Palladian architecture. A radical change came over the arrangements of houses under the new development, which had an effect on domestic architecture which lasted until recent times. The great hall was abandoned, and in its place was substituted an adaptation of the Italian cortile in the guise of a saloon. Houses were now raised on basements, and the one end sought for in planning a house seemed to have been not convenience, but symmetry. This symmetry was to be accomplished at all costs, and the arrangements, distribution, and dimensions of the different rooms were all alike subordinated to the ruling aim. The result was often, especially in inferior hands, almost ludicrous in the utter disregard of convenience displayed. When it is remembered that the Italian villa, which was taken as the model for imitation, was designed for habits and uses widely different from those of English gentry, it can hardly be wondered at that the houses of this period are often so ill adapted to their purposes.

The exteriors, again, of houses of this date show the attempt which was made to adapt the architecture of a country entirely different in climate to the requirements of this country. That the result was entirely satisfactory was hardly to be expected. In Wilton House, Wiltshire, and in many others of the houses which Inigo Jones designed, the "orders" are omitted, and the façades are treated simply as wall-spaces with window-openings, in which the effect is sought to be attained by an harmonious proportion of parts. The weakness of the style is betrayed by the necessity which seems to have existed for making the uppermost and the basement windows about half the size of those of the principal floor. It is this fault of proportioning the size of the windows, not to the rooms they were intended to light, but to some inflexible rule of proportion of the exterior, which makes the upper floors and basements of many country houses of the seventeenth and eighteenth centuries unreasonably dark and ill-ventilated.

During a great part of the first half of the seventeenth century building must have been almost at a standstill. With the Restoration, however, a new era in social history began. With the Restoration came the downfall and utter collapse of the Puritan system, and men's minds turned instinctively from the endless and purposeless theological problems and religious quarrels of the past to investigate and apply the laws of physical science. The establishment in 1662 of the Royal Society marked the commencement of a new period in study and knowledge, the influence of which on health and morals can hardly be exaggerated.

The fire of London, which, following closely on the last of the great outbreaks of

plague in 1666, destroyed the greater part of the city, was an occurrence of the utmost importance to the health of the inhabitants. The description of the city previous to the fire, given by Maitland, reveals a network of narrow, dark, and tortuous lanes, the houses mostly built of wood, and lofty, and each storey hanging over the one below, so as almost to meet at the top. To add to the obstruction to light and air, huge sign-boards were suspended across the centres of the streets. The sewers were in a most neglected state, and the drains all ran above-ground. Added to this, the supply of water, notwithstanding the formation of the New River in 1613, was very scanty. The practice of carrying the water into the interiors of houses first commenced in the reign of Charles II., and was at first viewed with considerable dislike, as tending to draw away the water to the detriment of the community.

The opportunity afforded by the destruction of so large a part of the metropolis was taken to promulgate certain very useful and necessary regulations. The streets were widened, though, as the narrow lanes still existing in the City show, not to the extent they might well have been; provision was made for the better drainage of the surface-water from the pavements of the streets; cesspools were formed to prevent the choking of the sewers by sand or gravel from the roadways; regulations were made for the due cleansing of the streets, and also for the orderly disposition of refuse; and all communication between privies and the public sewers was ordered to be cut off.

From the period immediately following the fire of London may be dated a steady decrease in deaths from plague, until, by the beginning of the eighteenth century, the disease had completely died out.

The rebuilding of the metropolis was the opportunity of one of the greatest architects of any age or any country. Such an opportunity, indeed, has rarely presented itself; and nobly did Wren avail himself of it. His first step was to prepare a plan for the complete rebuilding of the city, which, unfortunately, he was not permitted to carry out. The re-arrangement of the streets, which he proposed, would, if carried out, have made London one of the handsomest and most convenient cities in the world, and probably saved later generations much needless outlay in widening and improving streets. The short-sighted policy of our forefathers prevented this, and Wren had to do the best he could on the old lines.

Wren's principal works are his churches, of which St. Paul's stands pre-eminent. He carried out many very considerable works of domestic architecture, amongst which his additions to Hampton Court Palace are perhaps the best known.

As a specimen of his work, in a less pretentious form, the doorway to the old Merchant Taylors' School is a picturesque example. The interior of the school-room in the same building shows how a simple rectangular room almost entirely devoid of ornament can by skill in distributing and proportioning windows, and like attention to smaller details, be capable of presenting an entirely satisfactory architectural appearance.

The increasing use of brick, and the influence from various causes of Dutch architecture in this country, combined to produce a phase of classic architecture which, homely and simple in its details, was eminently suitable to the requirements of the country and the climate. Architectural effects were sought to be obtained by the use of such homely materials as red brick, with moulded and cut bricks for

cornices, pilasters, and the like, and deal or oak sashes painted white. A prominent feature in the phase is the double-hung sash. The frame brought out to the face of the wall, with its sashes and heavy-moulded bars, may be said to have taken the place of the tracery of Gothic times, and lent an interest to plain rectangular window-openings which had hitherto been wanting. It was the architecture of common sense, and its complete fulfilment of the requirements of domestic architecture in the present day goes far to prove its value. Chimney-pieces of quaint and curious designs abound during this period; and the fashion of panelling the sides of rooms, and forming elaborate ceilings of plaster-work, gives to houses of the time that air of homeliness and comfort so much wanting in work of a later period.

Though it is somewhat difficult to arrive at any very precise estimate of the sanitary condition of the great towns at the commencement of the eighteenth century, sufficient records exist to show that a steady increase must have taken place both in personal and public cleanliness. The average of deaths from colic and dysentery decreased with remarkable activity, so much so that in the last decennial period of the century the annual average of deaths from these causes was little more than a tenth of what it had been in the first one. The cause of this decrease is attributed by a writer at the beginning of the present century to the improvements which took place in all the great towns, in the manner of living, but particularly in respect to cleanliness and ventilation.*

In many provincial towns, however, the sanitary arrangements were but little in advance of those in the Middle Ages. In the year 1855, Mrs. Mary Bartlett, aged 105, described to Mr. Edwin Chadwick how, within her own recollection, it was dangerous to walk the streets of Exeter after dark "for fear of being befouled by what was thrown out of the windows, and during rain by the water-spouts from the unguttered houses."†

The old custom of strewing the floors with rushes also survived until the middle of the eighteenth century. In seaside towns sand did the work of rushes. Brussels carpets were introduced from Tournay in 1745, and by the year 1760 the floors of all respectable houses were carpeted.‡

The subject of ventilation appears to have received little or no attention in this country until the close of the seventeenth and the early years of the eighteenth centuries.

John Evelyn, with a view to remedy the vast amount of evil caused, even in his day, by the volumes of smoke constantly emitted by factories of all kinds, proposed a scheme for purifying the air of the city, which, visionary and impracticable as it undoubtedly is, nevertheless commands respect on account of its author if not for its inherent merits. The scheme was, briefly, to relegate all factories requiring large fires to the district between Greenwich and Woolwich, and prohibiting the erection of such buildings near the city in the future. Interments in churches and churchyards were to be discontinued. All offensive operations, such as tallow-melting, slaughtering, and soap-boiling, were to be allowed only within a certain specified area. All the low grounds round the city, especially on the east and south-west, were to be laid out in fields of from twenty to forty acres separated from each other by fences or hedges enclosing a plantation of

* Heberden's "Observations on the Increase and Decrease of Different Diseases," 1801.

† Roberts's "Social History of the Southern Counties," 1856. ‡ Ibid.

a hundred and fifty or more feet round each field. These hedges were to be planted with shrubs bearing fragrant flowers, such as the sweet-briar, rosemary, syringa, musk, rose, lavender, bay, and others. The areas between these fragrant fences were to be planted with pinks, carnations, primroses, violets, cowslips, thyme, balm, and many other plants all chosen for the fragrance of their flowers or foliage. The fields within these gardens were to be planted with "wild thyme, others with beans, and pease, and blossom-bearing grain that send out their virtue at the farthest distance, by which means the air and winds perpetually fanned from so many circling and encompassing hedges and fragrant shrubs, trees, and flowers (the prunings of whose superfluities may in winter on some occasions be burned to visit the city with a more benign smoke), not only all that did approach the region which is properly designed to be flowery, but even the whole city would be sensible of the sweet and ravishing varieties of the perfumes, as well as of the most delightful objects, and places of recreation for the inhabitants." *

This ingenious scheme for ventilating the City of London was so far encouraged by Charles II. that a bill was prepared by the Attorney-General for removing the obnoxious trades to a distance. It never, however, got farther than this stage.

In the year 1664 Dr. Henshaw proposed a plan for ventilating sick-rooms by means of a pair of bellows and a copper pipe. The room was to be made air-tight, and air was to be forced in or drawn out by the bellows until the air of the room assumed the required density. Thus in cases of intermittent fevers the Doctor proposed to rarefy the air during the cold fit and to condense it during the hot fit.†

Probably one of the earliest attempts to apply a regular system of ventilation to rooms was that of Sir Christopher Wren at the House of Commons. At each corner of the room he formed, in the ceiling, a large square hole, over which he placed a truncated pyramid provided with means of opening or closing. It was expected that the heated air would ascend through these pyramids into the room above. Without any provision for assisting the up-current, the obvious result of this arrangement was that when the air of the upper room was colder than that of the House below, the air descended in cold streams on the members' heads. This defect Dr. Desaguliers was in 1723 called in to remedy. The method he adopted was to build two closets, each containing a fireplace, and by means of pipes from each of the pyramids to supply air from the House itself to feed the fireplaces. The plan, however, had the misfortune to interfere with the personal comfort of the housekeeper, who was disturbed in the occupation of her rooms by the ventilating arrangements. To defeat the operation she delayed lighting the fires until the House had met and had become hot. By this means the heated air in the closets descended into the still hotter air of the House, and so made matters worse than before. Dr. Desaguliers was again called in, and devised a "centrifugal or blowing wheel," which, worked by manual labour, was "able to suck out the foul air or throw in fresh, or to do both at once, according as the Speaker is pleased to command it."‡

* Fumifugium, p. 49.

† Bernan "On the History and Art of Warming and Ventilating Rooms and Buildings," 1845.

‡ "Course of Nat. Philosophy."

About this period attempts were made to provide ventilation to ships and gaols.

The first quarter of the eighteenth century is remarkable for the works of an architect of no mean talents, but whose works have been subjected to criticism of the most adverse kind. Sir John Vanbrugh had in a pre-eminent degree the faculty of skilfully arranging large masses: he also understood thoroughly the difficult subject of light and shadow. His compositions are grandly conceived, and carried out with a vigour and boldness rarely equalled. His principal work, Blenheim, the national monument of the victories of Marlborough, is, with all its faults, a magnificent palace. It is, as Gwilt says, "a bold and difficult design, uniting in one building the beauty and magnificence of the Grecian architecture, the picturesqueness of the Gothic, and the masonic grandeur of the castle." *

James Gibbs, the architect of St. Martin-in-the-Fields, London, and the Radcliffe Library, Oxford, was much employed, during the earlier part of the eighteenth century, in building both town and country houses. In all, the same rigid and meaningless symmetry was carefully observed. He published, in 1738, a large folio volume of designs for churches and houses, the descriptions appended to which are meagre in the extreme.

Passing over several architects of more or less repute, the brothers Adam, as architects whose works are at the present day receiving much attention, must be briefly noticed. To the eye of a classic purist, such as Gwilt, the taste of the Adams was vicious and corrupt, and their compositions depraved. A more eclectic age sees, however, in their work genuine efforts, often attended with considerable success, to adapt the rules of classic art to modern requirements. The river front of the Adelphi Terrace is justly admired for its quiet and appropriate beauty, whilst in the interiors, rich and elegant ornamentation was skilfully applied to walls, ceilings, and chimney-pieces. A noticeable feature of the Adams' work was the use of carved wood and carton-pierre in chimney-pieces. The use of the latter material enabled them to put more richness into the chimney-pieces of quite small houses than would have been the case had they been restricted to marble. The same measure of success cannot certainly be conceded to their most ambitious effort in the direction of country mansion architecture. Keddlestone Hall, in Derbyshire, presents all the worst faults of the period, and fully deserves the condemnation pronounced by Dr. Johnson, that the "immense sum the house had cost was injudiciously laid out." †

With George Dance this brief description of the progress of architecture in the eighteenth century may fitly be concluded. To this architect is due the design of what is still one of the most successful public buildings in London. In Newgate Prison, which has been cited above as an example of architecture devoid of ornament, Dance, "by simply setting his mind to think of the purposes to which his building was to be appropriated, without turning aside to think of Grecian temples or Gothic castles . . . produced a very perfect building." ‡ The façade is simply a great windowless mass, with a very ordinary governor's house in the centre, flanked on either side by doors, an arrangement which seems to suggest the dual purpose of the prison: for felons and for debtors.

* Encyclopædia. † Boswell's "Johnson," 1777.
‡ Ferguson's "History of Modern Architecture," 1862.

CHAPTER XXVIII.

MODERN ARCHITECTURE.

Influence of Greek Architecture—The Gothic Revival—Influence of Pugin—Growth of Eclectic Treatment—The Queen Anne, or Free Classic Style—Freedom of Choice.

THE early part of the present century was marked by the growth and development of two schools of architecture, each of which had an important and lasting influence on the art. The object of the one school was the study and adaptation of Greek architecture, and of the other, Gothic, or, as it was called, national architecture.

Until the publication at the end of the last century of the measured drawings and views of the remains of ancient art in Greece, by Stuart and Revett, little or nothing was known of classic architecture except as it existed in the Roman examples. When, however, by these and subsequent works the real character of the art as it existed in ancient Greece became known, it was seen how vastly superior its details, proportions, and particularly its sculpture, were to the Roman models. Once introduced, the style became the rage; no building of any pretension was considered complete without its Grecian portico, while more or less accurate reproductions of Greek temples became the mode for churches and chapels. The attempt to reproduce with cheap materials, and under totally dissimilar conditions, the exquisitely refined proportions and mouldings of buildings so little adapted for modern English requirements as Greek temples, failed as it inevitably must have failed. But the failure was due, not to the impossibility of adapting Greek architecture to modern needs, but to the fact that of only one phase of Greek architecture sufficient remains were extant to serve as a model for imitation. This phase was the one least likely to be appropriate to domestic architecture: the religious. Noble as are many of the public buildings erected in this style, as, for instance, St. George's Hall at Liverpool, and the older portion of the University College in Gower Street, it is now generally conceded that the porticoes and colonnades which, when attached to a Greek temple, had a definite and necessary object to fulfil, are in this country costly and useless luxuries. The extreme of absurdity is reached when, as at St. Pancras Church in Euston Square, a small copy of the Temple of the Winds was placed on a larger one, and both on a reproduction of the portico of the Temple of Minerva Polias, whilst the forms of captive Caryan women support the cornice and entablature of the vestries.

Greek domestic architecture may be said to have perished. Records, however, remain sufficient to show that it was, as might be expected, of a character quite distinct from the religious type. That Greek forms may with success be used in domestic buildings is fairly proved by the works of Messrs. A. and G. Thomson, of Glasgow, and of the school in France known as the Neo-Grec. In both cases an intelligent appreciation of the inherent beauties of Greek art has combined with a frank recognition of the needs of modern habits to produce a style at once graceful, refined, and free.

The revival of Greek architecture, though in one sense resulting in failure, had

a very important influence on the development of the art, not the least of which was the rise of a school of architects whose works must always command admiration and respect. The names of Barry, Cockerell, and Soane are a few only out of a long list of able and learned professors of the art. Sir Charles Barry was, as Mr. Ferguson remarks,* almost the only one of the architects of the Revival who seems to have perceived the hopelessness of the path they were pursuing. His works, of which Bridgewater House is a well-known example, bear evidence of careful and intelligent regard for convenient arrangement, together with a very high order of artistic skill. The fact that in spite of his strong Italian proclivities he produced buildings in the Gothic style which, even in these days of more advanced knowledge of mediæval art, still hold their own, is no slight testimony to the reality and scope of Barry's genius.

The revival of mediæval or Gothic architecture may be said to have been originated in a practical form by Horace Walpole. It cannot be said, however, that the art was ever entirely lost. It has been seen how gradual was the process of establishing classic architecture in this country, and how the two periods overlapped so that it is impossible to fix any exact line of demarcation between them. Curiously enough, at the very time that men were learning to despise as rude and uncivilised the architecture of their forefathers, a spirit of inquiry and veneration for these very monuments of antiquity was being cultivated, and the foundation was laid of the school of antiquaries which has endured to this day. In a word, the continuity of Gothic architecture may be said to have been preserved by the labours of Dodsworth, Dugdale, and their successors. Though Sir Christopher Wren erected some churches and other buildings in which he adopted the pointed arch, he was so manifestly devoid of sympathy with the style, and his details are so obviously classic, that his efforts in the direction of mediæval architecture cannot be regarded as having any permanent influence on the revival.

Horace Walpole, afterwards Earl of Oxford, was a man of whom it was said by a competent critic that he was "the most eccentric, the most artificial, the most fastidious, the most capricious of men. His mind was a bundle of inconsistent whims and affectations."† One of his whims was a fancy for Gothic architecture. In the pursuit of this fancy he altered and added to his villa at Twickenham until he produced the "grotesque house with pie-crust battlements," so well known by the name of Strawberry Hill. Here he surrounded himself with copies in plaster of details of all kinds and of all periods from ancient examples. To carry out the mediæval idea, his dining-room was the refectory, and the roofs were surmounted by crosses. The same spirit of indiscriminating imitation pervaded the whole house; his chimney-pieces were copied from tombs, his gate-posts from the piers of Ely Cathedral, while the battlements and merlons of fortified castles were reproduced in this eighteenth-century villa in wood and plaster.

To trace the progress of the Gothic revival from Walpole's time to the present would occupy more space than can be here devoted to the subject, besides being beyond the scope of the present work. Passing over then an interval of half a century, during which reproductions of Gothic architecture were characterised by an ignorance of the detail only equalled by the utter lack of appreciation of the spirit of the art, the period of the revival of the true form, and, in a great measure,

* "History of Modern Architecture."

† Macaulay, "Essays."

of the true spirit of mediæval art is reached. To the study of the art Britton, Le Keux, the elder Pugin, and other writers and artists contributed valuable aid. In the practice, Augustus Welby Pugin may be regarded as the pioneer. Endowed with rare gifts, a rich imagination, and a facile pencil, his works are still pre-eminent for the wonderful manner in which he caught the spirit and sentiment of mediæval art. With a ready pen and a keen sense of the humorous he satirised the modern efforts at Gothic architecture, contrasting them with the examples of ancient times. His "Contrasts," his "True Principles of Gothic Architecture," and his "Apology for the Revival of Christian Architecture in England," are evidences not only of his artistic skill, but of the real grasp he had of the subject. His remarks in the "True Principles" on architectural propriety are particularly apt and to the point. Speaking of Italian villas, he says, "Is there any similarity between our climate and that of Italy? Not the least. Now I will maintain and prove that climate has always had a large share in the formation of domestic architecture, and the Italian is a good illustration of the truth of this remark. The apertures are small; long colonnades for shade, and the whole building calculated for retreat and protection from heat; the roofs are flat in pitch, from the absence of heavy snow, and plan and outline are both suited to the climate to which the architecture belongs. But we demand in England the very reverse of all this for health and comfort. We cannot fortunately import the climate of a country with its architecture, or else we should have the strangest possible combination of temperature and weather; and within the narrow compass of the Regent's Park, the burning heat of Hindostan, the freezing temperature of a Swiss mountain, the intolerable warmth of an Italian summer, with occasional spots of our native temperature."

The work that Pugin began and carried on with the enthusiasm engendered by religious zeal as well as artistic conviction has been continued and developed by a school of architects whose works may be seen through the length and breadth of the land. Naturally the revival of Gothic was intimately connected with ecclesiastical buildings and restorations. And inasmuch as the details of the style, being of an entirely different nature from those of a classic form, which had been prevalent for so long a period, required for their execution specially-trained workmen, the cost of building was necessarily much enhanced. This circumstance, coupled with the inevitable connection in men's minds between Gothic architecture and ecclesiastical buildings, prevented the style from becoming, as its advocates hoped it would become, the vernacular style of the country.

The later developments of the Gothic revival are marked by an eclecticism and a freedom that has had the effect of preserving and greatly enlarging its scope. Restricted, as the earlier advocates of the style would have had it, to one type or period—the thirteenth century—and to one country only—England—the revival would probably have died out years ago. It was, however, recognised not only that England possesses several periods of Gothic architecture, but that for many purposes the fifteenth and sixteenth century work is infinitely better adapted for modern houses than that of earlier periods. The existence of valuable and numerous remains of mediæval art in France, Germany, and the Low Countries was also recognised, and ideas and details were largely drawn from these ample sources. Another fact was recognised which had been too frequently and deliberately ignored by the earlier revivalists. This was, that whatever style is adopted,

a first and paramount necessity is to adapt that style to the best-known rules of health and convenience of the present, and not to reproduce the imperfect and insanitary arrangements of the past ages as necessary accompaniments of the style.

This eclecticism has led by gradual steps to what is, in a certain sense, a revival, but is also a development, of the brick architecture of the latter part of the seventeenth and the earlier part of the eighteenth centuries. This phase of architecture, commonly known as "Queen Anne," whilst its details are classic in form, is nearly allied in its homely picturesqueness to Gothic. It is, in fact, an attempt to make the best of homely and inexpensive materials, and to develop a style which adapts itself freely to modern notions of comfort and convenience. That it is eminently suitable to the requirements of the class of house which of all others is most in need of improvement, both in arrangement and architectural character—the small villa—seems clearly established by the fact that even speculating builders are smitten with the Queen Anne mania, and are producing to the best of their abilities houses designed in that manner. The characteristic features of the buildings of this class may be said to consist of red brick, used either as dressings or for the entire wall surfaces; rectangular window-openings with sliding sashes and a liberal use of white woodwork; add to these, cornices and string courses of moulded brickwork and a perfect freedom of choice as to the roof covering and pitch, and a style is obtained which, whether it be reduced to its plainest possible conditions or elaborated to the greatest conceivable extent, is yet undeniably architecture.

The question then arises—Which of all these various styles and phases of architecture is the one most suited to the requirements of modern house-building? And with this question comes another—Is it necessary or desirable that one uniform style of architecture should prevail to the exclusion of all others? Leaving for a moment the purely æsthetic aspect of the second question out of consideration, it will be well to see how far the general adoption of one style would affect the economical part of the subject. In the one item of joiners' work, for instance, upon the proper construction of which so much of the comfort of a house depends, it is manifest that the cost of production will be materially lessened if, by the use of mouldings and other accessories of one uniform character, machinery be made generally available. Further, it follows that, in order to produce work at the cheapest possible rate, workmen must be trained and accustomed to work chiefly, if not wholly, of one school. In the earlier days of the Gothic revival, a circumstance which operated very materially against the successful adoption of the style was the difficulty which was experienced in getting workmen to carry out the details of the, to them, new art. In the simple matter of a door, the carpenter found that a Gothic door was an altogether different thing from the kind of door he had always been accustomed to. The framing was different, the joints were different, and the mouldings were different; and this difference of construction pervaded all branches of the art. From joiners' work to glass-painting, from metal-work to paper-hangings, a new school of workmen and designers had to be trained. It is clear that such a revolution as this must at any rate be costly in its inception. It is also equally clear that if the use of existing appliances for economising labour, of which machinery may be taken as an important example, can be adapted to a style in other respects suitable, that style cannot on economical grounds alone be rejected as unfit for its purpose.

The æsthetic phase of the question is one which admits of being approached from more than one point of view, and of which it is scarcely possible to affirm that any one particular doctrine is right to the exclusion of the others. It is certainly difficult to see how the necessity or desirability of the adoption of a uniform style can be based on historic grounds. Although in all times and in all countries some one style or phase of architecture prevailed for a period of greater or less length, it will always be found that the causes which led to the adoption of this particular style were directly connected with the social, moral, and intellectual conditions of the people. And unless a perfectly new style, which shall be the artistic expression of the thoughts and ideas of this nineteenth century, be invented, the analogy from history fails. The probability of the development of any such style seems at the present time remote enough—so remote, indeed, that it cannot be said to have even begun. For the present purpose, therefore, it must be sufficient to have regard only to styles which have an actual existence in fact.

Leaving out of consideration such obvious incongruities as Chinese pagodas, Hindoo temples, and Swiss châlets, forms which, applied to domestic buildings in England, are at once inconvenient and absurd, there remain two broad divisions—classic and Gothic—in one or other of which each of the various styles of art is comprised.

The classic division may be subdivided into Greek, Italian, and what is known as Queen Anne, or Free Classic.

Of Greek, it may be said that, as a style for general adoption, it is unsuitable on account both of its costliness and of difficulties in the matter of lighting and arrangement apparently inseparable from the style. The exceptions mentioned above, however, go far to prove that in able hands a free and intelligent version of Greek art may be made to conform perfectly to modern requirements. But these very exceptions only show more clearly that the successful application of the style demands more care and thought in design than the majority of modern dwellings are likely to obtain.

Italian architecture will probably for a long time to come be a favourite style with a great number of people. There are, indeed, many things to recommend it. Not only is it compatible with English notions of comfort and convenience, but it admits of the most ample amount and the freest distribution of light and air. It is as capable of being adapted to irregular or awkward conditions of site as Gothic, whilst it possesses a dignity of appearance which is lacking to some phases of the latter. For its successful application, it requires, however, the use of somewhat costly materials. Of these, undoubtedly stone is the most necessary. Translate such a house as Dorchester House or Bridgewater House into brick and stucco and the truth of this is obvious at once. What is true of the exterior is true also of the interior. The inlaid pavements, the marble staircases, the elaborately-decorated ceilings and walls, and other features of more or less costly nature are all necessary parts of the style. Brought down to the level of a stuccoed suburban villa it becomes poor and mean and cold. In place of the varied tints of the stone we get the dull uniform grey of Portland cement; in place of the rich and varied decorations of the interior we have cold white or grey marble chimney-pieces and blank expanses of whitewashed ceilings.

The style known as Queen Anne or Free Classic stands midway between

classic and Gothic art. While on the one hand its details and ornaments are borrowed or adapted from the former, its absolute freedom of arrangement, and its consistency with the use of the cheapest materials, are qualities derived from the latter. The use of the sash window, so dear to the English mind, is one of the most conspicuous as well as most valuable characteristics of the style. It seems, however, to be deemed necessary to the successful carrying out of the style that the heavy bars and small panes prevalent at the beginning of the last century should be reproduced in this. From a purely æsthetic point of view there is much to be said in favour of these features. The white sash-frame and thick moulded sash-bars take the place of the stonework of a Gothic window, and lend an interest which would otherwise be wanting. From a sanitary point of view, however, these small panes and thick bars must be unhesitatingly condemned. There is never in this climate an excess of light, frequently the reverse. It is then obviously unwise to place unnecessary obstacles in the way of access of light. If houses were constructed with the sides of the rooms entirely windows, the introduction of sash-bars of tolerable thickness would be justifiable. As, however, constructional and other reasons forbid such an arrangement, and as moreover large sheets of glass are obtainable at moderate cost, it follows that the area of light-giving surface should be as free and unimpeded as possible.

Coming now to the second of the two groups into which the various styles were divided; the term Gothic may be taken to include besides the pointed styles (Early English, Decorated, Perpendicular, and Tudor), Elizabethan and Jacobean. Much has been written, and many houses have been designed to prove that Early English is a style specially suited to the needs of modern domestic architecture. Twenty years ago or thereabouts, there was a general concensus of opinion among the leaders of the Gothic revival, that the period at which church architecture in this country attained its highest pitch of perfection was the latter part of the thirteenth century. If, it was argued, this is the period most suitable for our churches, it follows that it is also the one most suitable for our domestic buildings. For, it must be remembered, the revival of Gothic architecture was, for a long time, confined almost exclusively to ecclesiastical buildings; the contention, therefore, of those who wished to overcome the popular prejudices against a style, associated in many minds with certain phases of religious thought, was, that a style to be good for anything must be equally applicable to ecclesiastical and secular purposes.

Following up this line of argument the conclusion naturally arrived at was that thirteenth century Gothic was the period of architecture which should be reproduced in domestic and secular buildings. Admitting, for the sake of argument, all that can be said in favour of the perfection arrived at by Gothic builders in the thirteenth century; admitting also the advantages of reviving the art of that period for ecclesiastical purposes in the present day, it by no means follows that its application to domestic purposes is equally advantageous. In the first place, it will probably be conceded that if the Christian church possesses one element of undisputed nature, it is that the lines upon which she is built were laid down and her fabric perfected eighteen centuries ago. She is not, like society, a changing and improving body for the simple reason that, fixed and governed by immutable laws,

change and improvement are equally impossible to her. Architecture as applied to dwellings is, on the other hand, as has been pointed out, constantly subject to change with the changing habits, and to improve with the increasing scientific knowledge of a people. If, then, it is necessary to go back to mediæval times to find architecture suited to modern requirements, it seems a reasonable stipulation to make, that the period selected shall, at least, be that nearest in point of civilisation and domestic refinement to the present. These conditions are best fulfilled by the later phases of Gothic, the Tudor and Elizabethan periods, both of which are capable of most successful adaptation to modern needs.

Whatever style or phase of architecture be chosen, whether classic, Gothic, or a blending of both, its forms, proportions, and details must all be unsparingly submitted to the test of fitness and conformity to the laws of sanitary science. While uniting all that is best in the past, it must freely adapt and incorporate all that is valuable in the inventions and discoveries of the present. New materials, new inventions, or new methods of applying existing materials or inventions, must, so far as they are in accordance with sound principles of construction and design, be freely accepted and used. The architecture of the future must be eclectic, if it is anything. We must not refuse to

"Pick out treasure from an earthen pot."

Nor must we neglect to profit by the lessons which come to us enshrined in materials of more costly character.

INTERNAL DECORATION.

By Robert W. Edis, F.S.A.

CHAPTER XXIX.

MORAL AND SOCIAL INFLUENCE OF TRUE DECORATIVE ART.

Inferior Character of Modern Building—Its Influence upon Decoration—Evil Effects upon the Poor especially—Moral and Physical Effects of Unartistic and Unhealthy Surroundings—The Tendency to Extremes—The Æsthetic Craze.

In the present striving after the proper application of sanitary science to the improvements of our buildings, public and private, and in the adoption of the best-known appliances for the prevention of impure smells and other evils, with which, either from ignorance or carelessness, we have been content to put up for long years, there is clearly shown a desire on the part of the public generally to set their houses more in order, and not to leave to chance or to the speculative builder all those questions of the healthy treatment of the homes we live in, which are especially requisite for their proper sanitary state, and which may fairly be supposed to enter largely into the proper healthy condition of our minds and bodies.

As sanitation in decoration must largely depend upon the character of our buildings, and the simple, healthy treatment of the fittings of our rooms be necessarily influenced by the general soundness and fairly good artistic design of the houses themselves, it would be well if the local authorities of our cities and towns would insist upon all new buildings being carried out with good and proper materials at least, if they cannot insist on any higher character of design than is apparent in so many of our new streets and suburban villas and cottages.

So far as I can see, although the powers given under the Revised Building Act may prevent to a certain extent a portion of this grossly inferior character of work being carried out, they do not prevent altogether the erection of houses of the most inferior kind; for although, nominally, certain requirements are made by District Boards as to drainage and other sanitary arrangements, these are too often over-ridden by the cunning and rascality of the low-class speculative builder.

The Building Act is practically useless for any sanitary purpose. It leaves all questions of drainage, proper arrangement of sinks, cisterns, and traps, ventilation of rooms and drains, literally unrestricted in any way: it takes no note of inside construction as regards character and soundness of timber and joiner's work, or of the proper making up of plaster for inside work, nor does it interfere with any matter of heating or general healthy warming of the various rooms; and in fact leaves to the speculative builder full power to carry out the worst and most unhealthy class of building, quite regardless of all matters of sanitation, warming, or ventilation. The ground landlord for the most part is only anxious to have his

ground covered, and cares little or nothing as to the class of buildings erected, so long as his ground rents are secured. I could point out many districts in and about London in which six or seven hundred houses have been run up without any professional supervision, and all regardless of the first principles of the laws of health.

The district surveyor is, as a rule, powerless to prevent this class of building being carried out, and, with every anxiety to faithfully discharge the duties of his position, is obliged in a great measure to submit to the utter inferiority of workmanship and materials, so long as the mere clauses of the Building Act are complied with, the walls built of the requisite thickness, and other minutiæ attended to. It is impossible to condemn in too strong language all this class of work, which is annually increasing in the suburbs of our great cities and towns, to meet the increasing requirements of that class of tenants who are gradually being ousted from more valuable quarters, to make room for new streets and other improvements. How can it be possible to attempt to improve such buildings by any sound and healthy system of decoration? They would be but whited sepulchres, and no amount of care or thought could prevent their gradual decay and ruin; and until some better and more complete system of sanitary inspection shall be provided for, all such buildings must necessarily add to the unhealthiness of our large towns, and tend to the moral degradation of those who live in them, and whose misfortune, rather than fault, it is to be obliged to put up with such homes and habitations. In the fashionable suburbs of London and other large towns, innumerable houses are daily being put up, in which the work is of the commonest description: the plaster-work mixed with road-scrapings, which it is manifest must contain sickening impurities of the most unhealthy description; the woodwork of the trashiest and most flimsy character, unseasoned and utterly unfit for its purpose, so that in a year or two the joints are all shrunk, leaving places for the lodgment of dirt and dust; the paint, and oil with which it is mixed, of the cheapest and nastiest kind; the size used in the distempering of the walls and ceilings decomposed and stinking; the plumbing-work of the cheapest possible character, so that in a few years it requires entirely renewing; the space between the floors left full of wood-shavings and other matter which naturally become damp, decompose, and cause unhealthy smells throughout the house, which it is impossible to get rid of; the drains running as a rule from back to front through the whole basement storey, laid in on made-up ground with imperfect joints, so that the earth in a short time becomes saturated with filth; old materials glossed over with paint or whitewash, and everything about them cheap and nasty, so that the unfortunate tenant who has taken one of them on lease finds his or her rent doubled by the expense of constant repairs, or by making good faulty and defective work.

It is not to be wondered at that in such houses there is constant sickness, and a general sense of depression fatal to any sound state of bodily or mental health.

It has become a fashion amongst a certain class of critics to decry the present style or fashion of architecture; to tear it to pieces in curious jargon and mixture of wordy terms, to call it senseless, frivolous, and unmeaning, a bastard mongrel founded on nothing, having no proper paternity, and to bedeck and bedizen it with all kinds of senseless and ignorant terms. Any way, it is more honest and better

in every sense, constructive and artistic, than the pretentious shams and plaster imitations of Greek or Roman temples or Pompeian villas, or dressed-up anachronisms of Gothic, whether copied from the terra cotta work of Northern Italy, the thirteenth and fourteenth century erections of France and England, or the Renaissance types of the valley of the Loire. There is more homeliness and picturesqueness in the modern work than in half the erections of the past century copied from foreign examples, having no elements of English home life or feeling; and if there be no very high artistic element in a broken gable or in red brick fronts, they are, any way, better and more picturesque than sham pediments, useless balustrades, or stuck-on pilasters and unmeaning and unnecessary Gothic tracery and Italian trusses.

In the homes of the poorer classes the character of the work and workmanship is often of the most inferior kind: cheap, nasty, and absolutely unhealthy. All this wretched system of building which I have described, and for which we architects are in no way responsible, exercises an important influence for evil on those who are condemned to live in such houses, and, to my mind, fosters a carelessness and untidiness which affect materially the mental if not the bodily health of the occupiers. How is it possible to be cleanly or tidy in a house in which the walls are breaking out into patches of damp, the woodwork of floors or doors opening out into yawning cracks, resting-places for dirt and dust, which no amount of cleaning can get rid of? How can floors be kept clean wherein the joists and crevices are filled with decomposing filth? or how can walls be cleansed or dusted which are covered in places with mould, or blisters from faulty and bad materials? The most tidy housewife might well tire of attempting to put her house in order, when all these evils of bad workmanship and bad materials are meeting her at every turn; and thus she is often disheartened, and the moral tone of healthiness engendered by the desire to set things right in her house, and to make all things about her clean and tidy, is lost, by the feeling that no amount of care on her part can make clean or tidy the miserable materials on which she has to work. The spirit of tidiness in the house, once done away with, leads to untidiness in other things; makes a house dreary, wretched, and unclean, no longer the pleasant, cheerful home, but a miserable and dirty abode in which want of cleanliness leads in a short space of time to want of health.

I have written thus strongly upon the moral effect of bad building in the homes of the poorer classes of the community, because I feel that it is absurd and inconsistent to urge any better system of design or decoration which shall not be useful to them as well as to ourselves, and that it is hopeless to suppose that we can surround ourselves with beautiful art work if we leave the workers out in the cold, and think not as much for the improvement of their dwellings as our own. If everything about our cottage dwellings is miserable and squalid, hideous and unartistic, how can we expect that those who must find the hearts and the hands to carry on our own work well and properly, can be attuned to truth and beauty in form or decoration, when their own surroundings are hideous and unartistic? If we are to expect any real art knowledge in our workmen, we must surround them with things of beauty. All the teaching in the world in schools of art will not produce a race of art workmen if the lessons are not exemplified, in however humble a degree, in their own home life,

and if the work and design which they have about them are tasteless and ugly. These views may perhaps sound far-fetched and Utopian to many of my readers, but I am quite certain that they will appeal to the common sense and better feeling of a large class. If we provide pleasant-looking homes, comfortable in their arrangement, and truthful and sound in their construction, for our poorer friends, we may suggest easily pleasant and inexpensive ways of rendering them more artistic and decorative, by the use of distemper colour or of the innumerable good coloured illustrations now to be found in almost every cheap magazine or illustrated paper, for pasting on the walls; thus imparting into the humblest cottage some element of artistic taste which may influence the dwellers therein to a more careful regard for their homes, and a greater spirit of cleanliness and tidiness, which tend in so large a degree to the healthiness and comfort of the dwelling.

It is well to remember that a large proportion of our own servants come from these very homes; that the influence of their early home life will materially tend to our own comfort; and that the lessons learnt in their own homes will bear good or bad fruit when they enter into service. The influence of early associations will make all the difference in bad or good servants, and we may be quite sure that those who have been brought up in pleasant and cheerful homes and surrounded with things pretty and artistic, in no matter how small a degree, will be better and more satisfactory as helps in our houses than those who have lived their young life amidst surroundings miserable, squalid, and unartistic. They will appreciate imperceptibly good art and good decoration in our own rooms, and will take care to be cleanly and tidy in looking after them without being constantly overlooked, and will add materially to the comfort and enjoyment of ourselves.

In the "Recreations of a Country Parson" there is an excellent chapter on the "Moral Influences of the Dwelling," and I find therein a quotation from Dr. Southwood Smith which seems to me worth repeating here as exemplifying all that I have said on cottage homes:—"A clean, fresh, and well-ordered house exercises over its inmates a moral, no less than a physical influence, and has a direct tendency to make the members of the family sober, peaceable, and considerate of the feelings and happiness of each other; nor is it difficult to have a connection between habitual feelings of this sort and the formation of habits of respect for property, for the laws in general, and even for those higher duties and obligations the observance of which no laws can enforce. Whereas, a filthy, squalid, unwholesome dwelling, in which none of the decencies common to society—even in the lowest stage of civilisation—are or can be observed, tends to make every dweller in such a house regardless of the feelings and happiness of each other, selfish, and sensual. And the connection is obvious between the constant indulgence of appetites and passions of this class, and the formation of habits of idleness, dishonesty, debauchery, and violence." Not only in the cottages of the humbler classes, but in the better-class houses of the upper middle classes there is an absence, as a rule, of any true system of sanitation, either in the fittings or general furniture of the house. It may be that some attempt has been made to rectify defective drainage and to put the house to a certain extent in order, but in many cases this is done without thought or care, and the result is, as may be imagined, unsatisfactory.

In all matters of the mere decorative treatment of our rooms, there has been evinced an almost equal amount of carelessness as of ignorance, and until quite recently we have been content to paper, paint, and whitewash our buildings without any regard to their healthy and proper decorative treatment. The sanitation of the house has been thought to consist merely in the proper arrangement and ventilation of the drains, and the ventilation of the rooms in some form or other; but the first elements of fitness and simplicity of treatment, harmony of colouring, and suitability and common sense in the covering of our floors, the decoration of our walls, and the furnishing of our rooms, would seem to have been utterly neglected; so that it would, a few years back, have been deemed absurd to discuss any question of wall painting or papering, or any arrangement of floor-covering or general treatment of the furniture and fittings of a house, from any mere sanitary point of view.

For many years we have been content to cover the whole floor-surface of the rooms with carpets, under which dirt and filth naturally accumulated, to exclude light and air by heavy fluffy curtains, to form resting-places for blacks and dust by the use of internal Venetian blinds, and to fill our rooms with lumbering old-fashioned furniture, with flat or sunken tops, which formed dirt and dust traps, rarely cleaned out. We have covered our walls with papers absolutely deleterious to bodily health, and have had but little regard to the mental effect of jarring colours and patterns, or the nervous irritability which almost unknowingly is excited by the use of badly-designed furniture, incongruous and staring decoration, and vulgar anachronisms in household taste, all of which, I believe, exercise to an important degree an influence equally damaging to our mental as bad drainage and improper ventilation do to our bodily health.

Twenty years ago, few people knew or cared much about the artistic character of the surroundings of their daily life. The ordinary English homes were fitted up either in the dreariest monotony of commonplaceness, or made gaudy with paper-hangings and floor-coverings of vulgar colouring and design. The carpets were covered with sprawling festoons of flowers, or with impossible grotesques of birds, beasts, and reptiles, in utterly unnatural treatment and senseless repetition. Flock papers of monotonous shades darkened our rooms and acted as traps for collecting all the filth and dust that could be absorbed from foul and unhealthy vapours, or collected from the dirt and smoke that gradually accumulate in every house. Not only were they inartistic and subversive of that mental enjoyment or pleasure which good and harmonious colouring tends to produce, but absolutely unhealthy; engendering a feeling of stuffiness and impurity, by constant absorption and accumulation of the various impurities which prevailed in rooms which were more or less closely shut up, and in which no proper arrangements existed for healthy ventilation. The gold or metal work in the ornaments soon got black and shabby; the fluffy nature of the material collected and held dust and other impurities, which no amount of brushing or cleaning could entirely get rid of.

Then the floors were covered all over with oil-cloth or carpet, and formed pleasant and safe collecting-places for dust and dirt, which was only partially got rid of at the annual or biennial periods of spring and autumn cleaning, and in times of sickness held closely to all the effluvium and infection, to the almost certain spread of diseases

and, at all events, to the always general unhealthiness of the house. The pleasant association of harmonious and grateful colouring, of a healthy treatment of surface decoration by which a higher mental tone is inspired, or of any artistic arrangement of the wall or floor-surfaces, were utterly unknown, and everything about us was trashy, vulgar, and commonplace. Gross shams and vulgar imitations in everything pertaining to dress, decoration, and furniture were not only accepted but delighted in; the age of "hoops" and other enormities in dress was equally satisfied with an utter disregard of moral or mental satisfaction in the decoration of the house, and cared little or nothing for the truth, fitness, and comfort of its internal belongings.

In matters of taste there has been, and will always be, great difference of opinion; but as the sense of sight may be said to become interested and affected from our earliest childhood, long before our other senses become fully or practically developed, it is but fair to assume that the harmonious treatment of colours and the arrangement of artistic forms with beauty and grace will naturally exercise an equal amount of healthy influence on the sense of sight, as the proper sanitary arrangement of our homes, and the cleanliness and purity of our surroundings, do upon the especial senses with which they are connected —taste, touch, and smell.

The child is amused and interested by being shown coloured pictures, and it is surely a matter of importance that, so far as possible, the teaching of the eye or sense of sight shall be of a good rather than an inferior order, and that it should be considered quite as requisite for healthy life, that the fitting up of the homes we live in should be pleasant and suitable, and the things we surround ourselves with harmonious and beautiful in their form and colour, so that the lessons which they are imperceptibly teaching for all time should be of a truthful and healthy character, as that the food we eat should be of good quality and properly cooked, and that the general sanitary state of the dwelling be as perfect as possible. A child may not at first be able to distinguish the difference between good and bad drawing, or between harmonious and crude colouring in the picture-books which are set before it; but surely the intellectual teaching of good art in beautiful drawing and colouring will imperceptibly tend to the healthier teaching and gradual and higher mental development in all matters in which the sense of sight is concerned, quite as much as well-selected and well-written books tend to foster purity of thought and language. It is not, therefore, too much to assume that "the girl or boy who grows up amidst harmonies of form and colour, and intelligent application of material, imbibes therefrom a spontaneous notion of what is meant by practical taste in its every-day uses; and it is not going too far to say that the art-disposition of such a child is fined down, and is rendered more delicate and more subtle by early association with good models, and that its power of appreciating the beauties of nature is, in consequence, strengthened and extended."

In most of us the sense of touch is at once appealed to by contact with any impurity or disagreeable body, the sense of hearing is jarred by listening to discordant sounds, or by noises which are harsh and out of character with the ordinary harmony of speech or music; while the organs of taste and smell are immediately appealed to by any impurities or nastinesses with which they may come in contact.

Why therefore should the most important sense of all, sight, be so utterly neglected, and its healthy and proper development uncared for, by an utter disregard of beauty either of form or colour in our general surroundings, and by a constant association with things that are crude and ugly, glaring and vulgar in colour, hideous and misshapen in form?

In an admirable and thoughtful article by Mr. Watts, R.A. in the *Nineteenth Century* of February, 1880, on "The Present Conditions of Art," occur the following words, which to my mind mark essentially the reasons of the present degenerate and unhealthy state of all matters pertaining to domestic arts in the present day.

"The untiring interest, the pains, the love bestowed formerly upon the perfecting and decorating of almost all objects of daily use, even when the service required was most material, is one of the most striking points of difference between ancient, or mediæval, and modern life. . . . Our confirmed habit of regarding art and all that belongs to it, all the delights that come to us through the medium of the noblest of all our organs, as necessarily separated from the serious business of life, must be fatal to art. The necessity for, and instructive delight in beauty, must be felt before we can hope to see great art flourishing healthily. The eye must appreciate noble form and beautiful colour before the jar consequent at the sight of ugliness is felt which would as a rule prevent its existence. In our modern life the cultivation of the eye is sacrificed to all kinds of meaner considerations. Other organs of taste are respectfully treated. Few people lightly value the importance of the cook's preparations. The well-dressed dinner is not put off till Sunday; to be indifferent to bad smells would be to confess defective organisation. Sounds are serious matters. We make efforts to escape discordant noise, or submit with grumbling. But with regard to the eye we submit habitually to conditions which are equivalent to tearing raw meat with our fingers and teeth, living in the midst of vile odours, and complacently enduring abominable discords."

To a great extent our manufacturers have it in their power to bring back a healthy artistic tone in everything we use; the commonest articles of daily life may be just as well beautiful in form, harmonious in colouring, and good in decorative design, as ugly, crude, and vulgar. It is no more costly to make our ordinary pots and pans, cups and saucers, silver and glass, beautiful, than it is to make them trashy and hideous. The simplest designs, if beautiful and graceful in shape, are infinitely more preferable in everything, than the costly productions covered with stuck-on ornament or badly-designed painting or engraving.

In all the commonest articles of daily use and necessity, there may be grace and simplicity of form without the unnecessary and unmeaning overlaying of bad ornament, which is not only useless but costly, liable in glass, china, or pottery to be easily chipped and broken, difficult to clean, and, as a rule, utterly useless. Fitness for the special purposes for which the various articles are intended, and common-sense treatment of their form and shape, should be the true aim of all manufacturers, in the design and make of the innumerable objects of daily use.

It must be evident to common-sense people, that all furniture which collects and holds dust and dirt which cannot be easily detected and cleaned; that all window-valances and heavy stuff curtains with heavy fringes which cannot be

constantly shaken; and that all floor-coverings which are fastened down so that it is impossible to clear away the dust that gradually but surely finds its way under them, and prevents the coverings themselves from being constantly shaken, are objectionable and unhealthy.

In the present craving after artistic decoration and furniture, and improved sanitary arrangements, it may be that we are running to the other extreme, frightening ourselves unnecessarily, and by overdoing the remedies which are recommended and provided for us by all the various experts in sanitary science or art decoration, inflicting damage, which by more careful thought and intimate knowledge of the why and the wherefore such remedies are to be applied, we might well avoid.

All new doctrines are, however, liable to be carried to extremes, and it is only by real knowledge and experience of years that we can hope to arrive at that happy medium, in which the true shall be separated from the false, the wise from the foolish. Whether it be in the adaptation of art or science for the improvement of our dwellings, we can hardly expect after so many years of utter disregard of the first principles of truth and fitness in all construction, sanitary and artistic, to begin an age of improvement and real progress without falling into some of the many pitfalls which the various professors of the new schools of sanitary and artistic improvement naturally lead us to, when as yet they are not agreed themselves on the best principles or means for carrying out the especial theories which they advocate.

Pet schemes are like pet dogs, nuisances to be avoided as much as possible; and common sense should, I take it, enter largely into all matters that are to be permanently useful to mankind, whether it be in sanitary appliances for the better drainage and water-supply, or in the more healthy and truthful decoration of the houses we live in. It may be said that the two things are not capable of comparison; that science depends only upon facts and the results of much experience and many failures, while decoration is a matter of taste made up of many theories and dependent to a great extent on the individual fancy and caprice, or upon the amount of knowledge or ignorance, as the case may be, either in the individual or the artist.

It would be easy enough to combat this argument by pointing out that there are almost as many opinions, differing to a large degree, in questions of sanitary science, as in those pertaining to truth and taste in decoration; various sanitary professors will tell you that "traps" are deadly, while others will assert that you cannot "trap" too much. The professors of artistic decoration differ materially in their views, and are not yet agreed on the, to my mind, fundamental principle that all good decoration should be truthful and based on construction, that all things should be beautiful in form and colour, whatever that form or colour may be. Whatever may be our own particular fancies or caprices as to form and colour, the one should be essentially fitting for its purpose, graceful in its treatment, and truthful in its construction; while the other should be harmonious and pleasing, without any flaunting crudities or vulgarities which, to the really educated or refined mind, are as objectionable, and, in their way, as morally and mentally, if not bodily deleterious, as any other impurities or imperfections with which we may be surrounded.

After long years of absolute indifference, and in a great measure of absolute ignorance in most matters pertaining to artistic taste, there seems to have taken place a remarkable awakening to the badness and vulgarity of the general decoration and furnishing of the houses we live in; and with this awakening, so to speak, from utter carelessness as to the artistic and truthful, or even healthy character of colouring of our walls and of the fittings we surround ourselves with, has set in a fashion which is encouraging better taste and more truthful work in our homes. But, unfortunately, with all this greater interest in the artistic treatment of our buildings, there is evinced, to a large extent, a want of real knowledge of, and love for art for its own sake, founded on practical education and trained judgment. Fashionable wall-papers and fashionable furniture, called after some particular period of design, are made to do duty for honest thought and study, by which alone any proper or lasting knowledge can be attained. Absurd forms and useless and expensive conceits in design run riot in papers, carpets, and hanging stuffs. Vulgar display is often preferred to simplicity of treatment; the use and purpose to which the various pieces of furniture are to be put are almost entirely lost sight of; the striving after novelty of form causes the real value of the particular article of furniture or fitting to be materially decreased: the shams of so-called high art or æstheticism are preferred to good and simple forms, useful shapes, and common-sense arrangement, whether it be in furniture or mere decorative fittings. Mere fashion, like all caprices dependent upon popular or individual change, cannot in the nature of things be lasting or real: a new fashion and a new craze will set in, and condemn all present arrangements based upon ignorance or mere imitation of the art of other countries, which, in nine cases out of ten, is utterly unfitting and inappropriate to modern requirements and the existing social life and feeling.

The great importance of a proper scientific training is being acknowledged in our public and private schools; we may well hope therefore that ere long a higher artistic training will also be insisted upon, and the knowledge of art form and colour will be eventually found as necessary in the education of an English gentleman, as is the knowledge of writing, reading, and arithmetic. Without this early education it is hopeless to suppose that the masses of even the educated public, with all the assistance offered by the innumerable mass of things artistic brought together in the museums and private collections of Europe and this country, can properly and thoroughly understand what is really good and truthful in art, or can properly appreciate good painting, good decoration, or good form in design of furniture or fittings. With the slightest elements of real artistic education it would be quite impossible for the mass of the public generally to put up with, or in any way be satisfied with, the atrocious vulgarities and the absurd anachronisms in the design, form, and colour of the innumerable small objects of every-day use.

So long, however, as ignorance reigns supreme, and the dogmas of some particular school of false teachers are blindly accepted as sound and correct, we must be content to see Fashion hold its own, and pander, in whatsoever way it and its exponents choose to insist upon, to the ignorance and sentimentality of the large and numerous following who accept the teaching as correct, because they themselves are entirely ignorant. This kind of unhealthy teaching, founded

on no true knowledge, can only lead to false results. For a time we shall be nauseated with all the sickly sentimentalism of washed-out colours, which are called Queen Anne, with all the nonsense and flimsiness of construction peculiar to some special school of eighteenth-century furniture, or with the imitation of Chinese, Indian, or Persian decoration—as unfitted for modern homes as the dress or life of the particular people is at variance with English home life and the social conditions of English society. It must not be thought for a moment that I am decrying the *study* of the exceedingly beautiful art of these or any countries. I am only objecting to the slavish, and ofttimes utterly unappreciative, imitation of examples of ancient art which are made to do duty in modern so-called artistic decoration. While we learn and study ancient and modern languages, we do not attempt to substitute them for our own English tongue in ordinary conversation or writing. Why then should we be content with the feeble and generally grossly travestied imitations of the art-work of other countries, in place of a more truthful and healthy treatment, founded on real knowledge and study, suitable for modern requirements and everyday homes in England. The art-work that was fitted and appropriate in the houses of Pompeii, or adapted to the walls of a Greek temple or Chinese pagoda, has nothing in common with English home life; and its imitation, however faithful and satisfactory, is as false and as bad as the pretentious imitation of marbling or graining so much affected in the decoration of houses of the earlier part of this century. Art, if it be worth having at all, must tend to the ennobling and refinement of all, and by appealing to the higher thoughts and feelings which are in us, help to satisfy the want which the eye, once properly educated, craves for and requires in all its surroundings.

Æstheticism is the fashionable name by which the new craze, for it is nothing better, goes, and is fast becoming a bye-word and a subject for scorn in the world to æstheticism in dress may, I take it, be traced the extraordinary fashions which in late years have found favour in washed-out colours and senseless affectation of peculiarities of shape and form, which, with a certain number of people, are supposed to represent high artistic culture and taste.

CHAPTER XXX.

PRINCIPLES OF INTERNAL DECORATION.

Evils of Pretence and Over-ornament—Back-grounds to be Unobtrusive—Discriminative Treatment—Contrasted and Associated Colours—Evils of Conspicuous Regular Pattern—Simplicity and Harmony.

As a first principle in all true decoration it must be always borne in mind that good ornament should invariably be associated with, and form an integral part of, the real construction of the building. If this principle were always understood and adhered to, the cost of the generally trashy composition and plaster-work with which the ordinary builder has thought it necessary to over-lay the walls and ceilings of our houses would be considerably reduced; all this over-laying of sham constructive ornament is not only bad in taste and expensive, but oftentimes a source of danger, and always an element of dirt in our rooms. What can be more hideous and more useless than the elaborate plaster or *papier mâché* cornices which are generally to be found in every modern house, in which long lines of recessed mouldings, and trumpery cast enrichments of the worst possible design answer no practical purpose, and serve only as recesses and resting-places for dirt and dust, while the elaborate and vulgar centre-flowers and corners which are stuck on to so many of our ceilings are so far an element of danger that they add materially to the thickness of the plaster-work, and being altogether false in construction, are liable to give way and fall down at any moment; in themselves are entirely opposed to any true principles of decoration, and if picked out in various colours according to the fashion usually followed by the general run of decorators, are eye-sores in the room, and in every way objectionable and out of place. Simple plain mouldings, or hollows to take off the stiffness of the square break between the walls and ceilings, are all that are necessary, without enrichment or stuck-on ornament of any kind; these breaks can then be treated in a quiet and simple manner, and help to improve the general decorative effect of the rooms, whether they be papered, painted, or distempered.

From every point of view these constructional shams are objectionable. They weary the eye with their long monotonous multiplication of the same moulded truss, leaf, or flower; they are essentially false and untruthful, and so far are opposing elements to the association of fitness and reality which are so eminently desirable in everything around us; they are conducive of dirt and dust wherever they occur, and must naturally thus add to the stuffiness and unhealthiness of the room; while at the same time they are opposed to all true taste and artistic beauty and simplicity in the decorative ornamentation of our walls and ceilings. In objecting to all such constructional shams as these, I am anxious that it should be understood that I do so, not only upon the point of taste, but on the more substantial basis that they are, to a great extent, elements of useless expense, and tend to deaden the mind to an unhealthy and careless disregard of false art and construction, and so far to prevent any better feeling for true taste in decoration. Shams of all kinds are to be objected to, whether it be in expensive and pretentious plaster or *papier mâché* ornament, unwieldy and pretentious trusses to windows

or mantelpieces which support nothing, and are often so badly set on that they can hardly hold themselves up, or in the imitation of other materials by use of graining and marbling. What can possibly be worse in taste and so utterly cold and miserable as covering staircases or other walls with paint or paper in imitation of blocks of marble or granite, or so trumpery and tasteless as graining woodwork in imitation of various woods; perhaps, as I have seen in many instances, satin-wood or maple for one side of a door, with dark walnut or wainscot on the other side; and after all, when this is done, it is a miserable travesty of the real material, and deceives no one who really knows anything of the particular materials the graining is intended to represent. This, I may be told, is an argument in its favour, that it deceives no one, and therefore does not matter; but the intention is the same, and whether the lie be well or badly told, it is a lie, any way, and so far subversive of a healthy turn of mind or true artistic feeling.

"In art," says Mr. Redgrave, the late Art Inspector-General at South Kensington, "a back-ground, if well designed, has its own distinctive features, yet these are to be so far suppressed and subdued as not to invite especial attention; while as a whole it ought to be entirely subservient to supporting and enhancing the principal figures—the subject of the picture. The decoration of a wall, if designed on good principles, has a like office; it is a back-ground to the furniture, the objects of art, and the occupants of the apartment. It may enrich the general effect, and add to magnificence, or be made to lighten or deepen the character of the chamber; it may appear to temper the heat of summer, or to give a sense of warmth and comfort to the winter; it may have the effect of increasing the size of a saloon, or of closing in the walls of a library or study; all which, by a due adaptation of colour, can be easily accomplished. But like the back-ground to which it has been compared, although its ornament may have a distinctive character for any of these purposes, it must be subdued, and uncontrasted in light and shade; strictly speaking, it should be flat and conventionalised, and lines or forms which are harsh or cutting on the ground should be as far as possible avoided, except where necessary to give expression to the ornamentation. Imitative treatments are objectionable on principle, both as intruding on the sense of flatness, and as being too *attractive* in their details and colours to be sufficiently retiring and unobtrusive."

I believe it has been shown by experiment and observation, that, to a certain and distinctly appreciable degree, various colours act upon our optic nerves to their fatigue and injury, and so far to the weariness and unhealthy action upon the brain, and that therefore it is a matter of interest to us how far we may use colours which present an harmonious and pleasant contrast to the eye, or which fatigue and annoy us by their harshness and inharmonious arrangement. Quite certain it is, however, that proper and harmonious contrast and arrangement of colours is an important question in all artistic decoration, as by proper contrast various colours may be made to look more beautiful and effective, while a dingy and unpleasant effect may be easily produced by any bad or violent combination; and, as a natural consequence, the graceful and pleasant appearance of our rooms will be naturally enhanced or decreased by a study and knowledge of the contrasts and effects of various colours. Without being able to define the exact shade, and even sometimes the

exact colouring, of any room we enter, we are sensibly affected pleasurably or the reverse by its general tone and treatment; even as in admiring good taste in dress we may not always be able to describe what it was that caused our special delight or admiration. How often do we hear it said that this or that lady was well dressed, and on being asked for a description of the dress or colour we are unable to remember or describe it. In the like manner, the prettiness and general pleasant effect of a room is often marred by some injudicious or inharmonious contrast of colouring or design in the paper or decoration, and ornament that should be in subjection and subordinate to the general effect is made staring and obtrusive, to the destruction of the artistic effect, and to our own mental annoyance. Without further entering into the physiological causes which enable us to judge between the proper and pleasant contrast and association of colours and the reverse, it will, I think, be admitted that a greater regard and attention to house decoration will pleasurably or prejudiciously influence our own comfort and health; and if this be admitted when our bodily health is good, and our nerves strong and vigorous, how much more will it be admitted when suffering from bodily or mental ill-health and fatigue. In the selection of paper or other hangings, and in the arrangement of all ornament in wall or panel decoration, it becomes therefore a matter of importance to select none which shall have distinct and strongly-marked patterns in which the ornament stands out and repeats itself in endless multiplication and monotony; all such patterns would be a source of infinite torture and annoyance in times of sickness and sleeplessness, would materially add to our discomfort and nervous irritability, and after a time have a ghastly and nightmare effect upon the brain.

Naturally the walls of various rooms will require different treatment. Halls and staircases should be of some warm, quiet tones of colouring, such as reds or greens which are not positive colours, as the eye on entering a house is generally fatigued by the strong glare of daylight; in the drawing-room, a good all-over decorative pattern, such as "Morris" blue pomegranate, or some of the generally decorative and well-designed modern French patterns, forms an exceedingly good covering, as being essentially gay and decorative without being especially defined in colour or ornament; in the drawing-room the wall-covering becomes often a material portion of the decoration, and is not usually required for a background for pictures or prints, and any good pattern in which the general colouring is brilliant without being gaudy, and in which the ornament and colours are so well arranged and balanced that they do not attract the eye by any strongly-defined pattern or colouring, may safely be used. In a dining-room or library, dull reds or warm russet-browns form good backgrounds for pictures or engravings, and even brilliant golden-flecked vermilion or quiet tones of blue, if relieved with enrichment or top friezes of warm vellum or lighter shades of blue and white, can be used with good effect, and do not by any means form disagreeable backgrounds. It must be manifest that the cutting up of any wall-surface by hanging pictures from the cornice-line by means of long cords or wires must be disagreeable in effect; if, therefore, picture-rods are used in any room of ordinary size, say from ten to twelve feet in height, they should be placed from two to three feet lower than the cornice, and be affixed to or form part of a small wood dividing moulding or rail. The top frieze, or surface, can be left plain or covered with a light self-tinted diaper paper,

or with arabesque enrichment, in one or two light shades of colouring, so arranged that they should not take away from the flatness of the wall-surface or attract the eye by too great prominence of colouring or ornament.

Dark golden yellow with russet and white ornament form also a pleasant general wall-surface when treated with a dado of dark brown or stamped leather: while all colours which contain oxide of iron, such as umbers, reds, and ochres, are serviceable and lasting. Good effects can also be produced on wall-surfaces by the use of a recently-introduced washable silvering, which is said not to tarnish and not to be injured by gas or atmospheric influences—in combination with black.

As all pleasant and artistic decoration must, to a certain extent, depend upon the proper arrangement of colours, and upon a knowledge of their various effects when placed in contiguity to each other, and the changes which take place under the influence of contrast, it will be useful to note a few of the more important changes in colours which are more or less largely used in the decoration of our rooms, whether with paint, paper, or distemper; and I give below a table compiled from Professor Rood's valuable book on "Modern Chromatics, applied to Art and Industry."

Pairs of colours.	Change due to contrast.
Red	becomes more purplish.
Yellow	,, ,, greenish.
Red	,, ,, orange red.
Blue	,, ,, greenish.
Yellow	,, ,, orange yellow.
Green	,, ,, bluish green.
Green	,, ,, yellowish-green.
Blue	,, ,, purplish.
Red	,, ,, purplish.
Orange	,, ,, yellowish.
Blue	,, ,, greenish.
Violet	,, ,, purplish.

Red placed on a white ground appears darker and more intense, on a black ground it becomes more orange in tone and more luminous; yellow on a white ground appears darker and more greenish than on a black ground, in the latter case it is particularly brilliant, and gives a bluish tint to the black ground. Yellow and grey or black constitute, therefore, a pleasant combination. Green on a white ground looks deeper and richer, on a black ground somewhat paler. Blue on white appears dark and rich, on black by contrast becoming more luminous. The eye tired by gazing at green, is rested by looking at its complement, *i.e.*, at a mixture of red and violet; vermilion with gold or yellow, or blue or greenish-blue, orange with green, sea-green with vermilion or violet, and red with blue, all give excellent combinations.*

A good yellow diaper on a bluish-grey ground, or grey ornament on light yellow or vellum ground, form good combinations for the upper portion or frieze of any room where the lower portion is treated with dark chocolate or purply-brown grounds. White ornament on soft blue or green grounds, similar to Wedgwood ware, is very effective, especially when applied to ceilings or friezes in which the

* From Professor Rood's chapters on "Contrasts" and "On the Combination of Colours in Pairs or Triads."

ornament is in low relief, as is the case in ceilings of the houses of the end of the last and beginning of this century.

How far different colours have any really practical influence upon the mind there are at present no reliable experiments to prove, but it is quite certain that various colours exercise distinctly-marked influences. Dr. Ponza of Alessandria has made various experiments in treating certain forms of insanity by the action of coloured light. The following extract from the *British Medical Journal* will explain the nature and theory of these investigations :—" Dr. Ponza's experiments consisted, in the abstract, in placing his patient in chambers coloured red, blue, and violet, with the most surprising results. In the red room he placed a melancholic man who had refused his food, but who three hours after wards was found lively and hungry. In the blue chamber he placed a violent lunatic, who became much quieter within an hour. In a violet room he procured equally good results. Of all the rays of the spectrum, the violet are those which possess the most intense electro-chemical rays ; the red are richest in calorific rays ; whilst the blue, devoid of calorific, chemical, or electric rays, are in fact the negation of all excitement, and are most useful in calming violent excesses of fury. It is said that Paracelsus recommended red coral as a remedy against melancholy ; while Esquinol and Rösch assert that indigo-dyers are melancholy, and those who dye scarlet are choleric."

To my mind nothing can be more objectionable and false in art than the overlaying of good coloured plain surfaces with flowers fossilised, so to speak, into unnatural forms, so as to present longways and crossways, and in any way in which you look at them, clearly-marked lines or patterns, or continual spots on the general surface, which fatigue the eye, and perceptibly set up mental irritation even in those who are in good health ; and which tend to the infinite discomfort and mental annoyance of those who are suffering from sickness or brain weariness. No matter how well-drawn or how artistic in general treatment, birds seemingly in flight, or cherubs holding festoons frozen into rest, seem to me utterly unsuitable for ordinary wall-decoration, by the absence in them of all quiet and repose. The pattern and colouring of a paper should be so treated that there should be no spotty effects, and no vividly-marked lines to break up the general surface into set forms. Plain colouring for wall-surfaces has the objection of showing scratches and finger-marks more easily than pattern papering ; but walls thus treated have a much more harmonious and quiet appearance, and can readily be broken up, if need be, with simple enrichment with good effect. Pure vermilion—toned with a little yellow chrome to take off its crudeness, and relieved with a darker surbase or dado, and some simple stencil-work in the frieze—or pure Antwerp blue, look very effective ; but both colours are too delicate to use in distemper, except on painted surfaces.

In all decorative art, whether it be in simple monochromy or single colour, or in its more elaborate treatment by use of polychromy in various distinct colours used simultaneously, much must naturally depend on the size and shape of the spaces to be treated. To quote the late Owen Jones, " The secret of success is the production of a broad general effect by the repetition of a few simple elements, variety being sought rather in the arrangement of the several portions of the design than in the multiplication of varied forms."

In all modern decoration there is to a great extent an absence of simplicity and natural harmony of colours, and a want of knowledge of proper combinations and contrasts, so that the wall-surfaces are either made flaming and vulgar in tone or cold and lifeless, when by a little thought and artistic judgment they may at the same cost be made agreeable and pleasant to the eye, and offer good back-grounds for the pictures and engravings which are placed upon them, or pleasant decorative effects in monochrome or polychrome. It is true that in most modern houses the work of the plasterer and the painter is of the most tasteless description, the proportion and contour of the mouldings, whether in ceilings, cornices and so-called enrichments, or enclosing-mouldings or architraves round the doors and windows, being generally coarse and bad, and offering no good constructive lines for decorative treatment; but there is no reason why the mere decorator should be allowed to run riot in over-laying every bit of bad enrichment—and thus emphasising its badness—with gaudy colouring or gold, or in picking out, as it is called, the various sham ornaments and mouldings with brilliant colouring, with no attempt at harmonious treatment or artistic blending together of tints and shades. The mere conventional decorator is a being to be avoided of all others, for his idea of artistic decoration would seem to be in gaudy colouring and gilt, utterly unnecessary and exceedingly expensive.

Gold used in decoration will not stand unless varnished, but becomes black by the effect of noxious gases and impure atmosphere, and in papers it is generally made up of inferior or Dutch metal, and soon becomes destroyed by atmospheric effects or draughts.

In the examples which are left to us of the decorative treatment of ordinary houses in Pompeii, the general arrangement of design and colouring was of great beauty and elegance in outline, and quiet and graceful harmony of colour; and when the ornamentation was in any way elaborated it was made conformable to the proportions of the rooms and in pleasant harmony and contrast with the furniture and general surroundings. We cannot but be struck with the brightness and cheerfulness and general artistic effect of the whole work. In the ordinary rooms the ceilings and upper portion of the walls had simple borders of graceful design in bright and well-arranged colouring, with occasional panels formed either by well-painted frescoes or ornament. Without desiring to see in modern rooms any imitation of Pompeiian decoration, we might study and adapt some of its graceful combinations of colouring and brilliant tones instead of picking out bad plaster enrichments in endless monotony of tints, or in stencilling hard and inartistic designs at various set intervals along the wall or ceiling space.

CHAPTER XXXI.

FLOORS AND FLOOR COVERINGS.

The Evils of Dust—Carpets as Sources of Dust—Substitutes for laid-down Carpets—Parqueterie—Painted Floors and Movable Rugs—Indian and Chinese Matting—Linoleum.

VERY recently there appeared in the columns of the *Times* a letter from a well-known surgeon, who, under the *nom de plume* of F.R.C.S., set forth his experiences of a London house, and his attempts, to quote his own words, to make it into a "wholesome and comfortable habitation."* The writer commences his letter by stating that the house had been immediately before him occupied by a well-known "sanitary reformer," and therefore was supposed to be in fair sanitary state; that it had been by him "swept and garnished, painted and papered, and presented a fair outside appearance." I cannot do better than quote his letter freely, as not only exemplifying to a great extent the evils which exist in so many of our houses, but the manner in which he eventually arrived at a fairly satisfactory solution of his difficulties, and established within his walls a healthy atmosphere, and, in a common-sense way, applied the various suggestions I have endeavoured to promulgate for the better and more healthy arrangement of decoration and furniture.

It is not necessary to follow the writer through all his preliminary troubles as to drainage, his discovery of what he calls a "honey-comb of cesspools" without any connection with the main sewer, and the various discomforts experienced from tribes of rats which infested the said cesspools.

In speaking of the furniture of the house, he says, "I had furnished the house in the way common to habitations of its class. There were window-curtains in the dining-room, window-curtains in the consulting-room, window-curtains in the drawing-room, window-curtains in the bed-rooms. There were carpets on all the floors; there were unprotected papers on the walls; there were wardrobes and other pieces of furniture, which had their apparent height increased by cornices, within which were hollow spaces, seemingly made on purpose to form harbours for dirt. There were ponderous book-shelves, containing a formidable amount of printed lumber, and a still more formidable amount of dust. The walls were old with uneven surfaces, and to these uneven surfaces dirt clung with an almost touching tenacity. There were all sorts of fluffy things about, which were supposed to be ornamental, fancy mats and the like, and which blackened the fingers of any one bold enough to touch them. Last, but by no means least, there were the ever-increasing accumulations of rubbish, such as old clothes, old toys, old books and pamphlets, old newspapers, old music, and miscellaneous trumpery of every description. Upon all these things the dirt of a London street poured

* I may fairly quote this letter as setting forth some few of the evils which may be altered or avoided, more especially as the writer, in concluding his letter, is good enough to state that "he derived the suggestions which first led him to think of perfect cleanliness as the highest domestic virtue from the various suggestions set forth" by myself in the series of "Cantor Lectures" which I delivered before the Society of Arts in the spring of 1880.

in without intermission. In dry weather the dust found its way through every chink; in wet weather the feet of visitors brought in mud, which dried into dust speedily. If the children romped for ten minutes in a carpeted room, the dust would lie in a thick layer upon the tables and chairs when they had finished. Dirt seemed to be omnipresent and all-pervading. It was plentiful in the air we breathed, it mingled with the food we ate and with the liquids we drank. The house, thus arranged, was a scene of perpetual *malaise* and ailing. Somebody always had a 'cold' or a headache, the former malady being now supposed to have little to do with temperature or with chills, but to be produced by the poisonous influence upon the mucous membrane of the respiratory passages of the septic dust which people breathe, and which, in the majority of instances, they trample out of their filthy carpets." After suffering in bodily health and general discomfort, and losing children and wife by seemingly untraceable causes, the writer goes on to say, "The conviction was at last forced upon me that we were placed under unwholesome conditions of living; and I set myself to consider how these conditions might be changed;" and in doing this the common sense of a professional man was at last brought into play. He began to realise that dust and dirt meant disease and illness, if not death; that dirt and dust could only be got rid of by getting rid of many of the generally-accepted forms of furniture and decoration, and that everything which tended to conceal dirt, and retain it, must be got rid of, and "that all dirt-traps, whether fixed or movable, should be abolished, and that all surfaces should be rendered washable. The first thing was to send away cart-loads of the varied material which I have already described as rubbish, the terms including all carpets, all window-curtains, all the muslin blinds which people hang across the lower halves of bed-room windows, all books and pamphlets which were not really required, all anti-macassars and the like, everything that was broken, and everything that was useless. Having thus cleared the ground, I commenced the work of reform."

"The first thing, of course, was to see carefully to the drainage and water arrangements, to the ventilation of the soil-pipes, the condition of the cisterns, and so forth. The next thing was to cover the old floors"—which as I have before said by their cracks and unevenness are among the worst possible forms of dust-traps, —"with thin oak parqueterie both in living-rooms and bed-rooms." This parquet veneering can be done for about the price of a good Brussels carpet, and should be polished, not merely waxed, so as to be easily cleaned. "It can be dusted or swept every day like the top of a table, or washed with a sponge and spirit of turpentine when dust is deposited upon it. The turpentine not only cleans it effectually, but also affords the benefit of its fragrant and antiseptic odour for some hours after it has been used." Upon the parqueterie floors thus laid and maintained, I have a few small Oriental rugs, each of which can be taken up and shaken in one hand. In the living-rooms they are dispersed about, in bed-rooms they are placed as hearth-rugs only."

It may be objected to by many people that the cold floor would be damaging to health by the sudden chill to the naked feet in getting out of bed, but this is easily remedied by having similar rugs or strips of felt or carpet laid alongside the bed on each side; while by such an arrangement the usual places for dust under furniture and beds is entirely avoided, and the healthiness of the rooms materially improved,

while the saving in labour in cleaning the room thoroughly each day is manifest, for there can be no difficulty in rubbing over the whole floor-surface thus treated with a damp rubber affixed to a flat broom, and thus at once cleaning and purifying the whole floor-surface. I may here suggest what I have always urged, that if this parqueterie covering is objected to on the ground of expense, the whole floor-surface may be painted in four good oils of a dark colour and varnished, at about one-third the expense, and answer for almost all practical purposes the same ends; but it cannot be too strongly urged that no floor can be kept clean if the chinks between the boards are allowed to remain as traps for filth of all kinds, and the uneven surfaces of the old floors be left rough for the accumulation of dirt and dust which no amount of cleaning can entirely get rid of. If the floors be treated with paint mixed to a certain extent with varnish, a smooth surface will be obtained at a moderate cost, the expense of carpeting the whole surface will be saved, and the ills of dirt and dust effectually prevented.

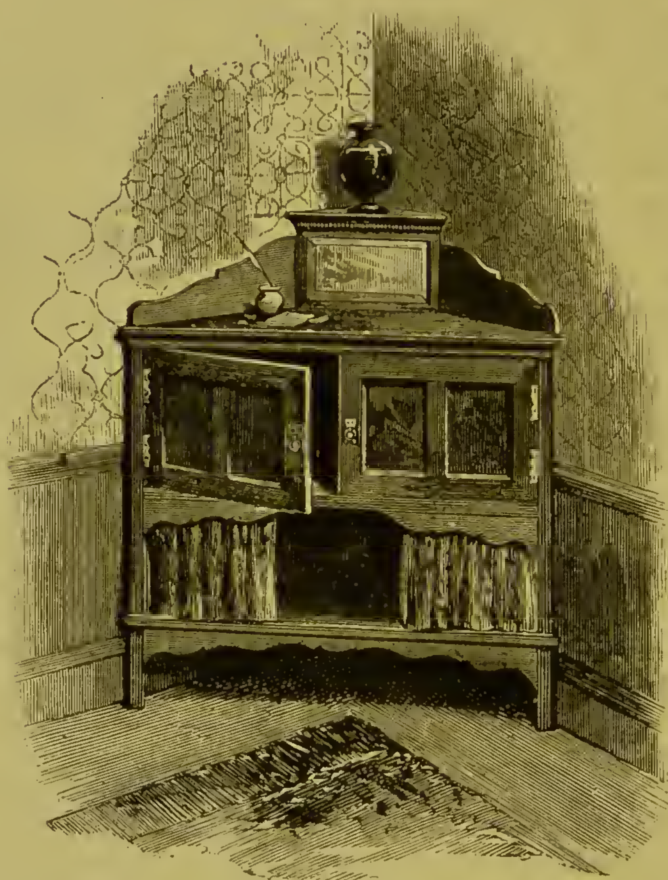
All this kind of painting and varnishing the floor-surfaces is infinitely less costly than any other kind of covering, carpet, matting, or drugget; easily cleaned, and as a consequence infinitely more healthy and satisfactory, and to my mind much more artistic and pleasant in its general tone and appearance than any amount of carpet or drugget covering. Good paint properly set with varnish or varnished over will last for years, and save all the annoyance and unhealthiness of carpets and annual or biennial cleanings.

In painting and varnishing the floors "sizing" should not be allowed, as it invariably chips, and is generally put on for the purpose of saving varnish. Good oil stain or three coats of paint should form the base for all varnished floors, and it is well also to remember that proper durability and hardening of all painted surfaces is in the main due to the quality of the paint used: raw oil as the medium of all painted work is naturally slow-drying and elastic, and if varnished before being thoroughly dry and hard, the varnish is apt to crack and chip: the surface of the paint should be covered with slow-drying varnish and carefully rubbed down between each coat.

Thin "carpet" parquet can now be obtained and laid down at almost the same cost as good Brussels carpet: glued down to the existing floors it forms an admirable non-absorbent covering, is easily kept clean, and is, in every sense, more healthy and more artistic than felt, drugget, or carpets. If polished with oil and beeswax the grain of the wood is, while being well filled up, clearly shown, and the whole can be kept clean and polished at a comparatively small expenditure of time and labour. Captain Douglas Galton, in his admirable little book on Hospital Construction, insists strongly upon "the walls and ceilings being quite plain and free from all projections, angles, or ornaments which should catch or accumulate dust." As regards floors, he says: "The floor should be as non-absorbent as possible, and for the sake of warmth to the feet it must in this country be of wood. Oak, or other close hard wood, with close joints, oiled and beeswaxed, and rubbed to a polish, makes a very good floor, and absorbs very little moisture. It is impossible to pay too much attention to the joints; they should be like those of the best *parqueterie*, affording no inlet for the lodgment of dirt; for the impurities which become lodged in the cracks of the floor are eminently objectionable. . . . Practically, with care, a well-laid oak floor, with a good beeswaxed surface, can

always be kept clean by rubbing," and thus the damp, which is necessarily engendered by constant scouring with soap and water, is done away with.

Until within the last few years it has been the custom to cover the whole surface of our floors, whether in the sitting or bed-rooms of our houses, with carpets fitted carefully to every angle and recess, and nailed tightly down to the woodwork. The ordinary cleaning has been done by sweeping over the surface, by which a certain amount of dust and fluff has been removed; but by far the greater portion, after helping to make the room foul for a while with clouds of filthy particles of



Angle Cabinet for Books, Papers, and China, Showing Movable Rug or Carpet.

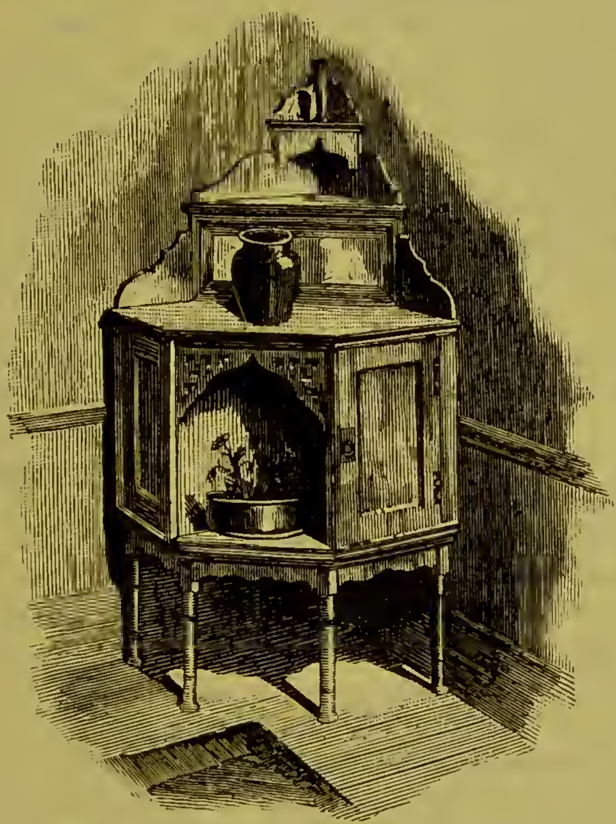
accumulated dirt held in suspense in the air, settles again, in part on its original resting-place, and in part on every piece of furniture and every ornament and projection in the room, necessitating constant labour in cleaning. For months this dust and dirt has been left to accumulate in and under the carpets, the floors never being washed, and the carpets never properly beaten and cleaned, until the usual time of spring or autumn "cleaning" took place, and thus infinite labour has been required to keep the rooms fairly dusted and pure.

It must be evident that the accumulated dirt and dust materially tend to keep the rooms stuffy and unhealthy, for it could hardly be expected that the labour and trouble, not to say expense, of unnailing, taking up, and relaying the carpet would be incurred oftener than necessary, and thus the floors themselves became

filthy, foul, and unhealthy, the interstices filled with putrefying dirt; all conducive to illness and unhealthiness.

The present fashion in taste is so far effecting an improvement, inasmuch as "fitted" carpets are the exception and not the rule, and have given way to central square carpets or scattered rugs, easily removable and cleaned, so as to admit of the whole of the floor-surface being thoroughly washed and purified at least once a week or month, while the side portions exposed can be kept clean and pure by washing over each day with a damp cloth.

In no room or passage should the floor-covering extend over the whole surface;



Angle Cabinet for Papers and China, Showing Movable Carpet.

and in no case should either carpet or rug be laid under any piece of furniture which is not easily removable, so as to admit of its being readily taken up for frequent brushing or cleansing outside the rooms.

In most cases the wooden floors of our houses, even where laid in the most careful manner, are liable to shrink, so as to leave spaces between the boards, through which dirt falls and remains boxed up for ever in the spaces between them and the ceilings under, or until the spaces themselves get filled up with soap and dirt after many years. Practically we must not wonder that there is generally a close and unwholesome smell clinging to the rooms, no matter how well they are ventilated, owing to the accumulation of decomposing and decomposed filth in the interstices of the boarding, which every cleaning only increases; while in the older houses the floor-boards—which are always wider than those in modern

buildings—have either shrunk or got worn in the centre so as to leave uneven surfaces, which all tend to unhealthiness by the spaces thus formed for accumulation of dirt and dust.

A remedy may be found for all this by carefully cleaning out all the dust spaces I have referred to, and by stopping them in with good oil putty, and then painting in four or five coats of paint, or staining, and wax-polishing the whole surface of the floors. By these means they will be made much less pervious to dust, and there will be no spaces left for its gradual accumulation; the dirt and dust will be much more readily seen on its surface, whether painted or polished, and the floors generally will be much more readily cleaned.

Thin oak parquet may be laid all round, or even all over the floors, where expense is no object, and in this a perfectly impervious and easily-cleaned surface may be obtained, which in itself will naturally be more lasting than paint or varnish, and will not require renewal for many years. I believe this can now be laid down for about sixpence to eightpence per foot super. On these painted or polished surfaces, square carpets, rugs, or matting can be laid, the borders being left clear, so as to form a pleasant contrast. The saving of cost would be considerable in all this kind of treatment of floor-surfaces, and the result infinitely more artistic and healthy.

It has been objected that rugs laid loosely on a painted or polished surface are likely to be dangerous to walk upon, and to slip from the feet: in answer to this, I can only say that I have used them for fifteen or more years, and have found no inconvenience, and if the objection were a fair or reasonable one, it could easily be remedied by pinning the rugs down with half a dozen large brass carpet pins, which could be taken out without trouble when the carpets or rugs are taken up for cleaning purposes.

We all know the amount of filth and dirt which is knocked out of a carpet at any of the so-called house-cleanings, and even if the carpet be in slips, or made in some fashion so as to be readily taken up and shaken once a week, it is quite impossible to get rid entirely of the dirt and dust which gradually saturate all woven fabrics, or which cling to their rough and fluffy surfaces. In the bed-rooms, therefore, all such floor-coverings would seem to be especially unhealthy, and it is but natural to suppose that these soft and porous surfaces easily receive and retain matters which, if not absolutely dangerous to health, are adverse to the proper sanitary condition of the rooms.

In rooms where carpets are, as it is called, "fitted"—that is, planned to the various recesses and irregularities, and then nailed down—it is evident that for many months the accumulation of dirt and dust must remain undisturbed, and the mere sweeping and brushing of the surface by the most cleanly servants only raises and disturbs the evil for awhile.

I am strongly in favour of substituting good Chinese or Indian matting for carpets in the sleeping-rooms of a house; as they must manifestly be less liable to collect and hold the dust and other impurities which cling to, and become ingrained, so to speak, in the woolly texture of a carpet, and which cannot be entirely got rid of even with the periodical shakings and beatings to which they are from time to time subjected.

The smoother surface of the matting is much less susceptible of receiving all

this dirt, and its glazed surface can be easily cleaned over with a damp cloth; the general tone of colouring is pleasant and agreeable, and although perhaps colder, is equally as soft to the feet as carpet; it neither absorbs dirt nor moisture like a woolly fabric, nor does it admit of particles of dust becoming ingrained in it as in carpet, while it can readily be cleaned every day with a little soap and water, and if laid down in strips on the painted or varnished floor, can be lifted and taken up, so as to allow of the whole floor-surface being scrubbed and washed once or twice a week.

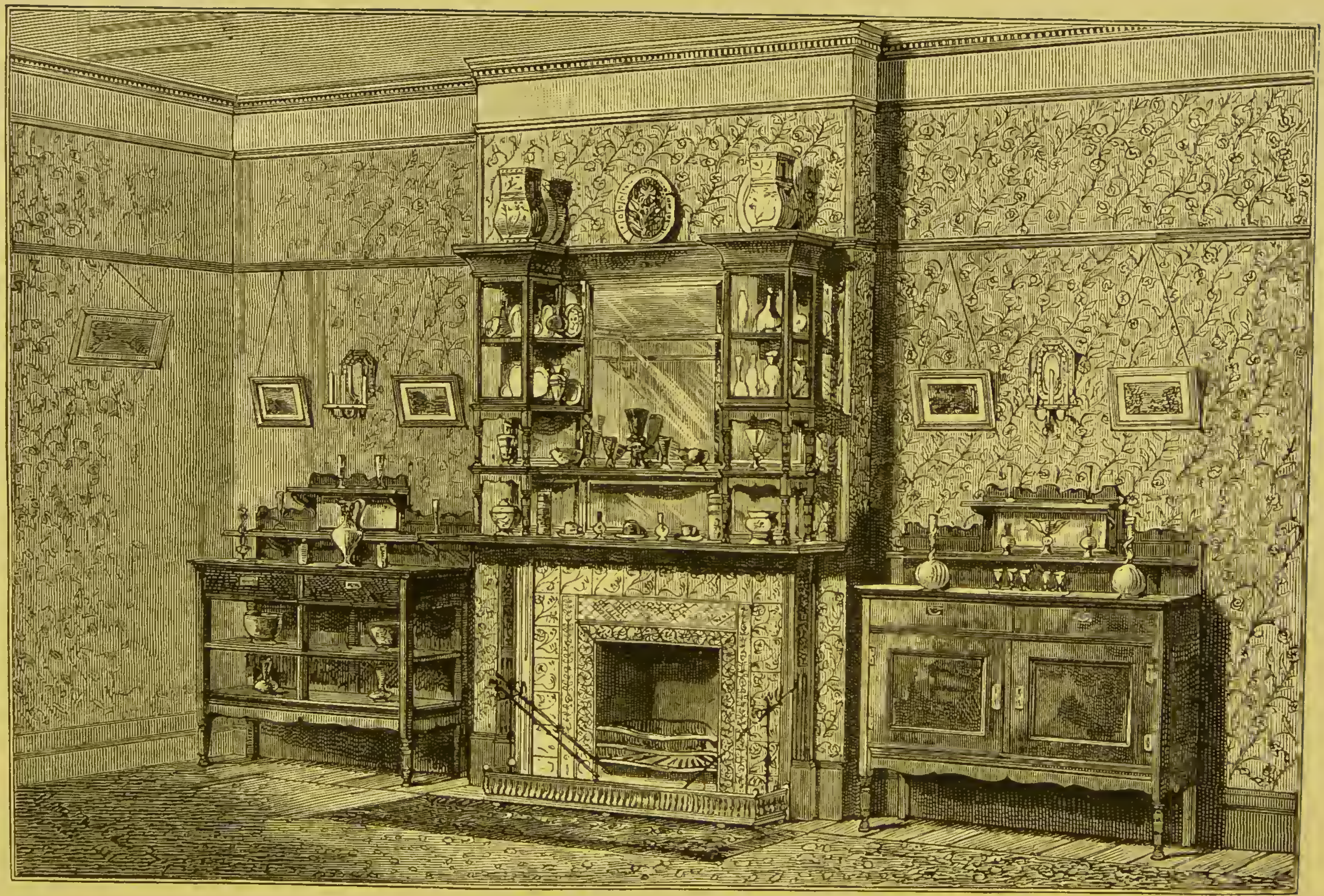
The thick Chinese matting, which is cool and pleasant to the feet, is made of reeds, and in its natural colour is of a soft greenish-white, pleasant to the eye and decorative as a simple covering on a dark-painted or stained floor. I have used it in my own house, and so far as I can judge, it does not get more shabby than ordinary carpet, and has the great advantage over this material of being easily removed, and not being retentive of dirt and dust; it can be obtained in different shades of colour, red, yellow, green, and blue, the various tints being obtained by means of dyes of perfectly harmless character; the cost varies from 3s. 6d. a square yard, and it is thus as cheap, if not cheaper, than carpet. In its manufacture all impurities in the reeds are removed in the making, the matting, after being woven, being dried in the sun, and afterwards over a slow fire; the material can be obtained in lengths or in square mats about nine feet long by six feet wide, or larger, so that there is no difficulty in adapting them to any room or space.

The Manilla matting is also well adapted for floor-covering where there is no great amount of traffic or wear; this is made from the fibre of the wild plantain, and is a kind of hemp; the delicate silky quality of the material is peculiarly adapted to receive all kinds of dye, and many of the specimens imported into this country are very decorative, although, unfortunately, in many instances, the influence of bad design is apparent.

Oil-cloth and linoleum have been largely used for floor-coverings in halls and passages. They are generally utterly bad in design, being made with patterns imitative of marble or tile painting, or parquet flooring, and when laid over the whole surface of wooden floors and glued down, as is often done, tend to promote dry rot in the floors by hermetically keeping out all air and ventilation. When laid with cement or other material so as to fix firmly and evenly to the floor-surface, they practically destroy it, and render it quite unfit for any future painting or staining.

A material has been brought out called "Lincrusta," which will be found useful for wall decoration, more especially as the merit of keeping back damp in walls is claimed for it; the designs are generally good and effective, and in the stamped and painted specimens I have seen, have been delicately and artistically treated in colour, whereby a pleasant and decorative effect is produced; the material is well adapted for the lining of walls and staircases in dados and panelling, and offers none of the objections I have raised to its use for floor-covering. Linoleum may safely be used if simply laid flat over the central portions of the floor and fastened down with pins, but it should on no account be laid over the whole surface, or allowed to be fixed down with cement. In many instances within the writer's knowledge the use of it as an entire covering has been the means of bringing dry

rot in the wooden floors, especially in those in which the ventilation underneath has in any way been imperfect or insufficient. There are now many kinds of linoleum which are not printed in patterns suggestive of other materials, and for hall covering where a large amount of wear is required it is perhaps better than any other material; but great care should be taken not to allow the workmen to cover the whole surface, or to put it down with cement or other viscous compounds usually employed



Robert W. Edis, *delt.*

DINING-ROOM FURNITURE: SMALL BUFFET, DINNER-WAGGON, &c.

CHAPTER XXXII.

THE WALLS AND WALL-COVERINGS.

Unartistic Character of a Monotonous Wall—Advantages of a Frieze—Simplicity of Cornice—Painting—Papering—Distempered and Painted Walls.

To my mind the covering of the wall-surfaces of our rooms from floor to ceiling with one hue of paint or paper, no matter how good it may be in colour or pattern, is utterly destructive of all artistic feeling. We are made dependent upon anything in the shape of pictures, prints, or photographs to break up and enliven the dreary sameness of the cold walls. We shut ourselves up, as it were, in a box with coloured sides and a whitened top, and were it not for the bits of life given by the things we hang on the sides, we might almost be driven mad with the everlasting sameness and monotony, whereas all this can so easily and effectively be remedied by the adaptation of some graceful design of coloured decoration, and by breaking up the flat surfaces into two or more spaces, filling the upper space with some pleasant decoration in stencil-work of festoons of flowers, figure-panels, or arabesques of conventional character, in which there shall be at least some semblance of bright and artistic colouring and drawing, and by treating the lower spaces with soft and warm general tints, which may either serve for a back-ground for pictures or drawings, or be sufficiently effective and harmonious in its pattern and colouring to do without either.

In ordinary wall-surfaces I am therefore strongly an advocate for dividing the space between the skirting and the ceiling cornice, not only as adding to the general size and picturesque appearance of the room, but as being more artistic and effective. Unless the ceiling be toned in colour, the effect of one tone of colouring on the wall-surfaces, no matter how good, is generally monotonous, and makes much too abrupt a division between the wall and the white mass of ceiling overhead; in many cases this abruptness is sought to be broken or modified by elaborate toning down, and what is called "picking out" of the generally bad plaster cornices, whereby the badly disguised and moulded ornament is made more pronounced, at a great expense and to the manifest damage of the artistic appearance of the room.

No cornice should be "picked out" as it is called; if the ornament be especially good it may be brought into relief, like Wedgwood ware, by slightly tinting the background, but generally it will be found undesirable to do more than tone down the whole cornice so as to harmonise with the wall-covering and blend it, as it were, into the ceiling, or at most it should be treated with two or three colours either harmonising or contrasting distinctly with the wall-colouring. The fashion of "picking out" the cornice enrichments with gold and many colours is not only offensive to the eye but eminently costly and artistically objectionable; it is not desirable to frame the mass of white ceiling with strong colour and gilt lines, so as to make it a blank picture overhead, nor, to my mind, is it in good taste to mark strongly the dividing-space between wall and ceiling. The general tone of the colouring of the upper portion of the wall-surface or frieze should be used in the

cornice and gradually lightened off to meet the mass of white or slightly relieved surface of the ceiling; strong containing lines may be used to emphasise or mark the junction of the frieze and the ceiling, often with good effect, if the lines be carried also on to the flat ceiling-space so as to avoid too abrupt a finish.

It is quite certain that pictures hung above a certain height on the wall are not only disagreeable to look at, and are imperfectly seen, but unpleasantly crowd the surface; and for this reason also I advocate the division of the wall into two spaces, the one next the ceiling being made as a broad frieze distempered to a uniform shade and treated with good figure subjects in oil or stencil decoration, or covered with a paper of some "all over" pattern of much lighter tone than the general wall-surface or lower portion of the room.

These spaces should be divided by a small moulding, from which the pictures may be hung; or the division may be made with a flat wooden rail, two or three inches wide and half an inch thick, and finished at the bottom with half or three-quarter inch gas-piping as a picture-rod; in this way the objectionable lines of wire or cord hanging down from the top of the room will be avoided, and the taking down of the pictures for dusting or cleaning be made much more easy than when hung from rods placed immediately under the cornice, and so high that they cannot be reached except by the aid of a pair of steps. I would here venture to protest against the coarse and vulgar character of most picture-frames, which with broad top surfaces and mass of unmeaning and generally bad plaster ornament help to collect dust and dirt, which rarely gets properly cleaned off. If the enclosing frame of a picture must be broad and massive, I cannot see why it should not be formed of some well-designed moulding with the top surface splayed back with simple mouldings towards the wall, so as to do away as far as possible with a large dust-collecting surface at the top; nor do I see any reason why the frame should be a mass of tinsel gold, which, in rooms where gas is used, soon becomes tarnished and dirty. It is hopeless to discuss the manifold evils and discomforts which arise from the filthy gas which is supplied by gas companies for lighting our rooms; we can only trust that electric lighting may ere long take its place in our houses and in our streets, and thus once and for all get rid of the terrible effects arising from the present system of lighting. The filthy compound which is supplied to us nowadays not only tends to destroy everything in our rooms, but seriously affects our health and comfort, engendering heat and foulness of atmosphere, which no amount of ventilation can effectually get rid of.

The proportion which the upper space shall bear to the lower must of course depend upon the heights of the various rooms, but there will be no difficulty in determining this if a piece of wood or moulding is "offered up" or laid along the wall surface and lowered or raised until the proper proportion of the division is arrived at. The illustration facing the preceding page, mainly designed to show some appropriate furniture, shows the usual proportion of such a frieze. The general proportion may, as a rule, be taken as three to one; that is to say, the upper space, or frieze, including the cornice, should occupy about one-fourth of the whole height of the room. In dining-rooms, where the chairs are generally, when not in use, placed against the walls, a chair-rail is essentially useful to protect the walls from being chipped or damaged. This can be made to help the decoration of the room by forming what is called a "dado." This dado. or lower space, should

be painted and varnished, so as to be easily cleaned, and the rail, or moulding, should be of sufficient projection to keep the backs of the chairs from touching the walls. As a further protection, a small angle fillet should be nailed on to the floor next the skirting, to keep the back legs from scratching or chipping the painted skirting.

The methods generally employed in finishing the wall-surfaces of rooms are painting, papering, and distemper. Without discussing here which is the better method to use, it is well to remember that paper, by its very nature and material, is naturally more absorbent than paint or distemper; holds damp, and is liable to be saturated with and to retain moisture, more than either paint or distemper; so naturally to a certain extent increasing the unhealthiness of the rooms. Paint, on the other hand, if finished in the ordinary way, has an unpleasant glaze or gloss, which shows all imperfections on the wall, and by its non-absorbent surface is liable to become smeared, and to show readily condensation in damp weather, if used for wall-surfaces. As a background for pictures it should be "flatted," or finished with a large proportion of "turps." Distemper is liable to appear damp in wet weather by absorbing and retaining the dampness of the surrounding atmosphere, and to become spotty in appearance; and unless a house is thoroughly dry and kept well aired the distemper-work is liable to fly and dry out in a patchy manner, which gives the wall an uneven and disagreeable appearance; but this, as a rule, will only occur when the rooms are shut up for any period, and are insufficiently aired. It is hardly necessary to say that both distemper and paper are likely to suffer materially if the rooms remain for any length of time uninhabited, or proper attention is not paid to the warming and ventilation of the house in damp weather. For ordinary rooms, therefore, paper is more cheerful and warm in its general appearance, and more suitable than paint for ordinary wall-surfaces where the plaster-work is not perfectly true and smooth. The general basis of most painted surfaces is white lead paint, which may perhaps be looked upon as the best protective covering to wood or plaster-work; when exposed to the fumes of sulphur compounds such as are evolved from decaying vegetable matter, or sewer emanations, it becomes dark and causes an eruption of black spots, as may often be noticed in the external painting of many basement storeys in town houses. Lead paint is coloured by the addition of various staining or colouring pigments. Great care should be taken in its use, as it is very liable to be absorbed in the system through the pores of the skin, and to produce a kind of paralysis, as well as the complaint generally known as "painters' colic." How far green paint is injurious to health I cannot pretend to say, nor does this part of the subject enter into the scope of this paper, but I strongly advise the use of compound greens, such as those which are made up of blue and yellow pigments, in place of those which are produced from copper and arsenic, and which although said to be more durable, are certainly more dangerous, especially when used in wall-papers or distemper; emerald-green and verdigris are especially unsuitable for this reason. There are, however, so many almost equally good greens which are perfectly harmless, and so many ways of making good decorative tints of this shade by the mixing of various other colours, that it is not to be supposed that green is in any way to be treated as a forbidden colour.

It is not part of the purpose of this article to enter into the vexed question of

arsenical colouring; but it may be mentioned here that green is not the only tint in which arsenical colouring is to be feared. I believe that lilac, certain shades of blue, pink, and French grey all contain arsenic to a certain extent, although, on the other hand, all good manufacturers nowadays are careful to avoid the use of arsenic in any of the colouring-matter of their papers, whether green or any other tint, and in selecting from the patterns of any good well-known firms, and indeed from those of any first-class manufacturer, the customer may be fairly certain that this most unhealthy ingredient forms no portion of the colouring-matter in the papers offered for his selection. This dangerous pigment is, I believe, now generally discarded by every good manufacturer, and the soft greens and blues which form some of the most artistic paper coverings of the present day may fairly be said to be entirely free from it. This matter, however, will be more fully dealt with in a subsequent chapter.

In all decoration great care is necessary in the proper selection and mixing of the various ingredients in accordance with the nature of the material to be covered, and the general appearance required in the work when completed. Delicate tints require colourless oil, while flatted surfaces must have no oil at all, or it will give an unpleasant sheen or gloss. In all good outside work boiled oil should be used, as it weathers better than raw oil; and turps or turpentine should be avoided as much as possible, as it evaporates and does not last, although a little is necessary to prevent the paint blistering.

All internal woodwork should be treated in flat tones of colour and varnished; the surface thus treated is easily cleaned and wears much better than when left, as is usually the case, unvarnished. It is essential for health's sake to carefully consider all these points; a little extra expense in varnishing the painted surfaces of doors, shutters, and the general joiner's work in a room will make the house much more healthy, and by the protective quality of the varnish save in the long run much labour and expense in re-painting.

Paper must necessarily be used for the ordinary covering of wall-surfaces, as being the most inexpensive manner of decoration which we have, and some of the patterns now made are highly artistic and good in design and colouring, and are offered to the public at a very small cost. It depends upon the chooser whether the wall-surface shall show a mass of meaningless and vulgar ornament, or whether it shall be pleasant in design and colouring.

As a rule, the most inexpensive papers are the best—quiet in colouring, generally good in design, and free from glaring patterns or spottiness of treatment. For three or four shillings per piece it is possible to select a paper which shall not only be in itself pleasant and artistic in colour, but suitable in every way as a background for prints or pictures, lighting up well by day and night, and sufficiently good in texture and quality to last for years.

Most of these papers can be cleansed easily with bread-crumb, and offer no surface projection for the lodgment of dust.

Many of the flock papers now made are especially beautiful in design, but they are, to my mind, quite unfitted for the wall-surfaces of a room. The patterns stand out in relief, and offer innumerable spaces for dust and dirt, while the general fluffy nature of the material, practically powdered wool, renders it more absorbent and therefore more unhealthy, and the surface holds dust and dirt to a much larger

degree than the ordinary printed papers, thus tending to a stuffy and unwholesome feeling, which is essentially at variance with all laws of health and comfort. Stamped papers, in which the pattern is raised in relief, offer the same objections in a minor degree, as the surface is smooth and can be readily cleansed; and in the case of the imitation leather papers, the surface is varnished, and can be readily gone over with a damp cloth without injury. These papers can be well used for the dados of rooms or for frieze decoration, and as such are exceedingly effective, although, of course, from the very nature of the manufacture, much more expensive than plain painting and varnishing.

In bath-rooms and water-closets it is most desirable that the wall-surface shall be as non-absorbent as possible, and paper, unless varnished over, should generally be avoided, and when used should be of some plain, simple pattern, and not a bad imitation of tiles or marble. The best kind of covering for all these places is plain buff or grey glazed tiling, which can be put up at moderate cost, and by its general cleanliness and non-absorbent quality adds materially to the comfort and cleanliness of the house.

To my mind it is very undesirable to choose papers which are very "pronounced" in colour or design, and extravagant in price, as for a few shillings per piece good decorative and well-designed papers can be obtained, and can be easily renewed at small cost, when the more extravagant paper would practically prevent, on the score of expense, any change. I have before me as I write a pattern-book of exceedingly well-designed papers, all printed in two shades of pleasant colouring—light grounds with darker-toned pattern, suitable for almost any room, and well adapted as backgrounds for pictures, all varying in price from one shilling to three shillings a piece.

There are now so many good paper-hangings made at a moderate price, that the selection of a really good artistic paper, good in general tone, design, and colour, is no longer a difficult task; the designs are for the most part good and well drawn, and the colouring harmonious and pleasing; in some of the designs there is a striving after quaintness, eccentricity, and a spottiness of colouring, to be avoided.

Papers in patterns, in books or in small pieces, look very different when hung, in mass upon the walls, and great care therefore is necessary in their selection. It is well to first of all select two or three patterns which seem the most suitable for the particular rooms in which the papers are to be hung, and then to get "pieces" or long lengths of each, and have them tacked on to the wall so that the effect and general tone may be seen in day and gas-light; for many papers that look well in the day-time are anything but pleasant at night, while some of the darker-toned papers absorb so much light, that when hung it may be found that the lighting arrangement in the room is altogether insufficient.

A good-proportioned and otherwise well-designed room is often absolutely ruined by the bad taste shown in the wall-covering, for which there can now be no possible excuse. A paper which may be hung in a dining-room is generally quite unsuitable for a drawing-room or a lady's boudoir; in the one a quiet dark tone of paper is required as a back-ground for prints or pictures, while in the drawing-room the wall-covering may be much more decorative in its treatment, so as to help the general decoration of the room. As a rule it is better to paint

than paper the walls of a dining-room, the less absorbent qualities of a painted wall being better for a room in which the fumes of dinner are likely to cling and last longer when the walls are papered; if, however, the walls be painted they should be finished with a flatting coat, so as to take off the gloss which I have before described.

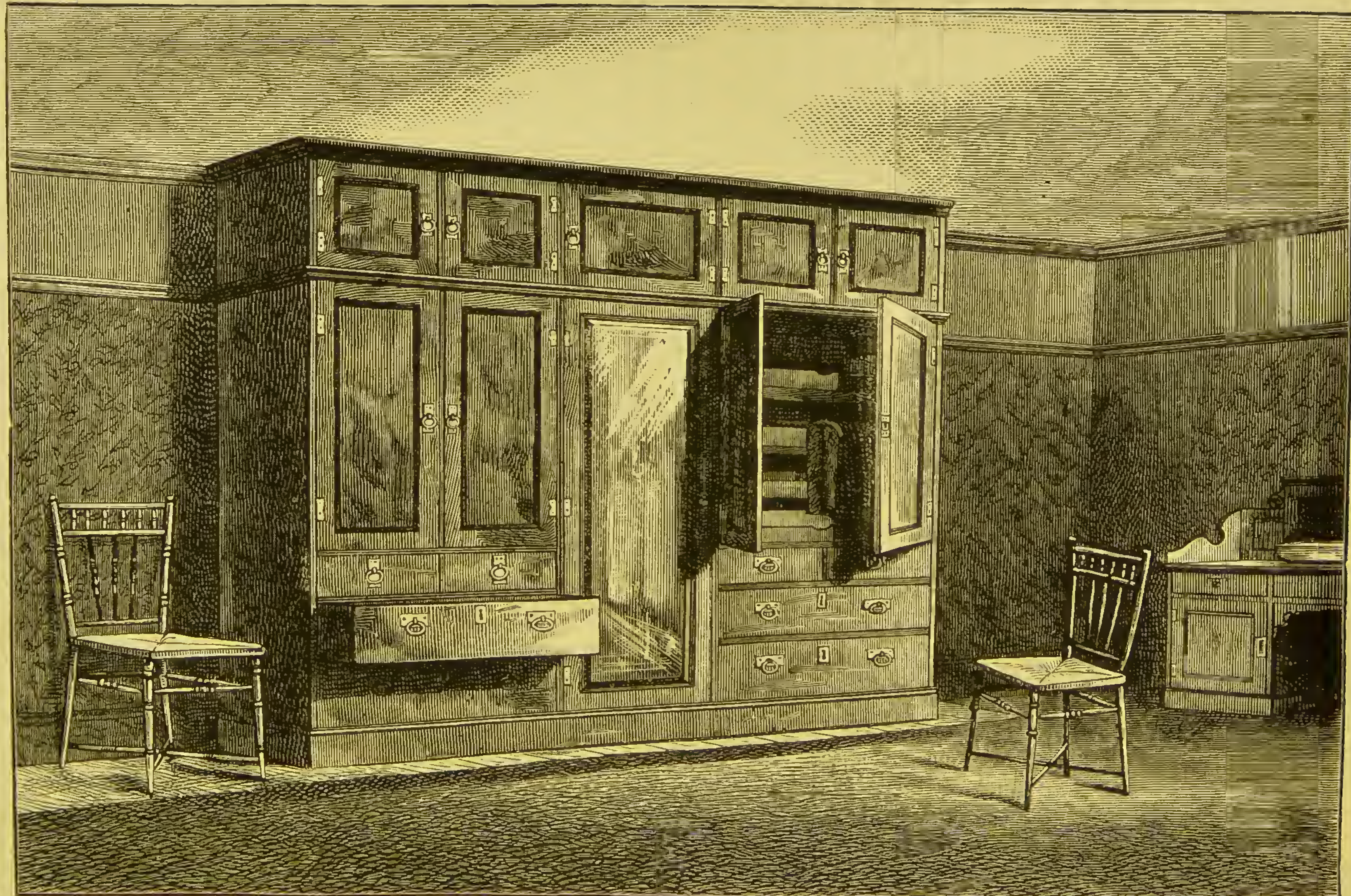
I may here mention that a good deal of illness often arises from the bad nature of the size and paste with which the ordinary wall-papers are hung, and great care should be taken that no such inferior and practically stinking materials are allowed.

M. Vallin in the *Revue d'Hygiene* reports an instance of the danger of this use of putrid size and paste. "A lady, who from time to time came to supervise the decoration of her houses, was three times successively seized with violent sickness and headache, after sleeping in a newly-papered room. M. Vallin was struck with the putrefactive odour which pervaded the atmosphere, and after examining into the matter, came to the conclusion that it proceeded from the wall. It was found that a horrible putrefactive odour proceeded from the size-pot, with which the paper-hanger, in the next room, was continuing to hang the wall-papers, and that his size was in a state of putrefactive change. On making further inquiries, various other cases have come under his notice in which illness has palpably been produced by the use, by paper-hangers, of size and paste undergoing or speedily entering on septic change; and it is extremely desirable that this should be borne in mind, and if necessary, a little oil of cloves, salicylic acid, or some other anti-septic agent should be added to the material which they use for this purpose, or, at any rate, care should be taken to avoid those disagreeable consequences of carelessness, which is only too common."

It is hardly necessary to point out how requisite, for health's sake, it is that every bit of old paper should be cleaned off the wall before any new paper is put on; as not only does the paste of the old papering often decompose, and become in itself injurious to health, but each covering of paper only adds to the absorbent nature of the walls, and helps to increase therefore the unhealthiness and stuffiness of the room.

Before any new papering is put on, the walls should be thoroughly scraped and washed down, to free them from the old paper and paste, and then be coated with size before the new paper is put on. There are various kinds of papers now manufactured which are said to be easily washable and to be non-absorbent, and thus to resist the contagion of infectious disorders, but I should imagine that it would scarcely be safe to trust to the *non*-absorbent qualities of any paper-hanging, and that after a case of infectious disease the walls, ceilings, and paint should be thoroughly cleaned and renewed.

Various papers are specially susceptible of damp, and should be avoided as much as possible. Amongst these are what are called satin papers, or those which have a glazed or polished surface like the French imitation satin or moiré silk papers; these are to my mind not only undesirable for this cause, but also on the ground of good taste and good art; equally with those papers which are made in imitation of willow-pattern plates, tiles, or marble; for when really good decoration, or plain pattern papers, suited to every taste, can be obtained at moderate cost, there is surely no reason for encouraging shams of any kind either in wall decoration or painting.



Bed-room Wardrobe with Top Cupboards and Drawers Combined.

There is a wall-covering manufactured consisting of a mixture of linseed oil and fibre, on which the ornamentation is stamped by machinery in low relief, suggestive of stamped leather-work, and sufficiently low in relief as not to offer any great amount of raised surface for the lodgment of dust. As practically it consists of a thick fabric of oxidised oil, it may fairly be said to be damp-resisting and lasting; and when painted it forms an excellent covering for the wall-surface of a hall or staircase, as from the nature of its composition it is less likely to be damaged than paint, paper, or other hard surface, being to a certain extent elastic, and therefore not likely to be damaged by the blows or other accidents incidental to the moving of boxes and furniture in the highways of a house.

I cannot advocate too strongly the greater use of distemper colouring for the walls of nurseries and bed-rooms, where for health's sake the wall-covering should be changed as frequently as possible, for with the greatest amount of care and cleanliness it must be evident that the absorbent nature of paper must necessarily cause it to retain a certain proportion of the deleterious atmosphere which cannot well be avoided in ordinary rooms where no special provision is made for the ingress of fresh and the egress of foul air.

Bed-rooms especially become tainted after a time by the impure air which is engendered during the long hours of night, when the rooms are closely shut up, and in times of illness; and there is no really effective way of getting rid of this tainted and unwholesome smell except by changing the wall-covering as frequently as possible, certainly at least once in every two years; distemper, therefore, for all such rooms becomes invaluable, for it can be washed off and redone in a few hours at a comparatively small expense, and the colouring may be as bright and cheerful as desired; the walls thus treated are not only much more healthy, but, to my mind, infinitely better than when painted or papered, being free from any specific pattern and spottiness, which have anything but a soothing tendency to those who may be suffering from illness or over-fatigue and taxation of the brain; and although the pigments used in the various colours are practically the same as those used for paints, the colouring-matter is much less, and common whiting is used as a basis instead of white lead or zinc white.

The basement should on no account have paper in any of the rooms, as it is obvious that the surface of the walls should be frequently washed down and cleaned of all impurities. This can be done at a comparatively small cost if distemper colouring be used; and the kitchen and offices in which our servants necessarily spend so large a portion of their time may thus be made cheerful, bright, and healthy. All woodwork throughout the house should be varnished, so as to be readily cleaned with a damp cloth without damage to the paint.

The wall-spaces of rooms thus treated can be divided as suggested for papered walls, and two colours or two different shades of colour used for the upper and lower spaces, by which a pleasant and artistic effect may be obtained; ornament may be easily added in stencil-work or simple lines. The accompanying illustration exhibits the effect, though chiefly designed to show the plan of the wardrobe, with top cupboards, as explained further on. Too great care cannot be taken in the selection of colours, whether in paint, paper, or distemper, so that they be pleasant and harmonious, not glaring and vulgar, and with no startling contrasts or effects, which are offensive to the eye.

CHAPTER XXXIII.

FURNITURE AND FURNISHING.

Specially designed Furniture—May be Cheap—How to Furnish a Dining-room—Bed-room Furniture—Evils of Flat Tops to Wardrobes—Truthfulness *v.* Sham—Minor Fittings.

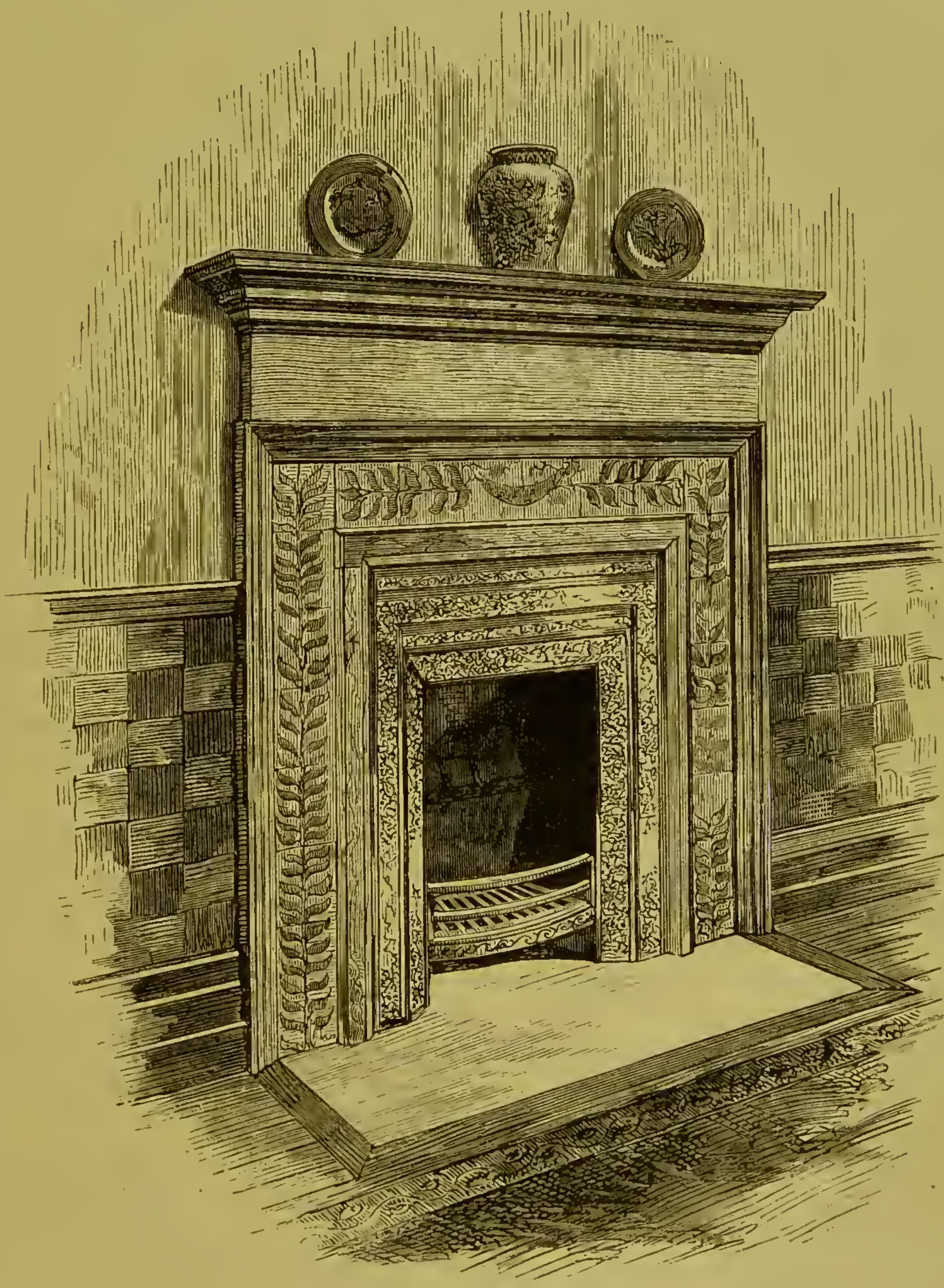
In furnishing a house, it is well to consider beforehand whether the recesses and window-spaces cannot be utilised for ottomans or hanging cupboards, and so save lumbering or overcrowding the rooms with expensive movable fittings, more or less ill adapted for their purposes; and, under all circumstances, the larger items of furniture will be found much more useful and satisfactory if they are made specially to suit individual requirements.

To quote a common-sense and practical article from *Blackwood's Magazine* on "The Arts in the Household," by Mr. Beavington Atkinson, a gentleman who has done much to foster and promote the more general use of artistic culture in every-day life :—"In a house, as in a picture, above all things shun crowded medleys of mediocre or common forms as you would the unkempt rabble of democracy. Strive against scattered, small, trivial, and frivolous effects. Even a mantelpiece may, by its purposeless and silly baubles, bespeak a childish intellect; each portion of a house should, as far as may be, receive the study due to each component part in a deliberate pictorial composition. In fine, the whole problem of" (decoration and) "furnishing may be summed up in the three words—form, colour, composition—terms known by every painter to comprise the whole world of art." The writer completes his article by insisting, as I do, "that domestic arts of decoration, however multiplied, scattered, or disordered, are not many arts, but one art united under common principles, and governed by broad generic laws; and finally, that the problem of how best to decorate and furnish a dwelling, finds a solution in the application to domestic uses of the few fundamental principles which preside over the master-arts of architecture, sculpture, and painting."

The different sketches which illustrate this article represent various pieces of furniture specially designed for special purposes, some of them combining different articles of ordinary furniture, so as to be useful for several purposes. The full-page illustrations show suggestions for fitting up a small dining-room, where the usual lumbering sideboard would occupy too much space; for a small buffet, with bookcase and top cupboards for papers, and for a large wardrobe, combining with it drawers and boot cupboard. The vignette drawings show suggestive designs for various small pieces of furniture, which can be adapted for almost any purpose. They have all been made for me by an eminent firm, in good sound deal, painted, to show that simple and useful designs can be worked out in an inexpensive manner, and that it is not necessary that specially designed furniture need in any way be costly. One of the small sketches shows a hanging cupboard specially designed for bed-room purposes. The drawers and cupboards are intended for medicine bottles and the other *desiderata* which no good housewife is ever without, the shelf for books, and the whole is suggested to be hung on the wall near to the head of the bed, with a simple writing-table under, an obvious requirement in most houses

Dining-room Buffet with Book-case and Top Cupboards,

where, to a certain extent, the bed-room is made a sitting or private retiring room. The small mantelpiece and grate were designed by me as cheap substitutes for the vulgar and commonplace box mantels and register stoves usually provided in the



Mantelpiece and Grate.

inferior rooms of a house. The grate costs from thirty to forty shillings, according to its size, and the mantelpiece, with tiles and marble complete, under five pounds. The grate has fire-lump sides and back, the latter made at an angle to throw as much heat into the room as possible, and to secure at the same time a good upward current to prevent smoky chimneys. The grate is so far successful that it accomplishes both these objects. The mantelpiece is made in various woods, and to

my mind is a pleasanter and more artistic object in a room than the usual boxed marble abomination, with its sham trusses and false and flimsy construction.

If, instead of the usual haste with which most people rush at furnishing or decorating their houses, seeking to choose in a few hours the whole of the fittings for the various rooms, a little more thought and care were to be bestowed on the selection of the various pieces of furniture, and as to their adaptability and fitness for their special purposes, there would be less useless lumber in our houses, and more comfort and artistic character in the fittings; for I hold that every piece of furniture not intended simply for ornament should be arranged for its special use, adaptable, of course, for various purposes, but fitted and planned as far as practicable to the walls, spaces, and sizes of the room it is to occupy.

I have been told that all this kind of advice and argument is absurd; that when people want to furnish, they have no time to wait for designed furniture, but must get everything done as rapidly as possible, and the house put in order for occupation; that it is better to buy the usual sets of dining or bed-room furniture, no matter how ill-suited they may be for the rooms they are to occupy, than think carefully first of all as to the special purposes for which they may be required, so long as they can be bought out of hand.

A vast amount of utterly useless lumber is crowded into rooms without any regard to its use or appropriateness, flimsily-made chairs hardly fit to bear the weight of a child, gimcrack tables quite unfitted to carry any weight, useless cabinets with circular corners, enclosed with glass to the floor-level, as if anything worth seeing would be put to be seen at the level of our feet, and a mass of trashy ornaments of inartistic and common-place character, bought seemingly to fill up the cabinets or to decorate the mantel-shelves. Many pounds are wasted in trash of this kind where the same money would, if properly expended, buy some really useful or artistic piece of furniture. But if our houses are to be treated as shops, and to be "stocked" complete before being opened, it can hardly be expected that there will not be a large amount of utterly useless and inartistic rubbish brought into them.

Common thought and common sense do not seem to be necessary elements in buying furniture, as they are in other matters connected with daily life, and the result is too often the filling of our homes with fittings which may look well enough in a show-room, but which, when we get them home, are found to be more or less unsuitable and incongruous.

A good many people buy ready-made clothing, and I dare say some of them get tolerably well fitted, but I fancy most sensible people choose their own cloth and colours, and have their clothing made to suit them, and adapted for particular seasons and purposes; why not apply the same common sense and taste to the furnishing of a house? It is all very well to say that almost any kind and character of fittings can be bought nowadays, but so far as my experience goes, most of the furniture offered to us is made after some particular fashion, good, bad, or indifferent, without reference to its suitability for the place each piece may have to occupy, with all kinds of expensive, and utterly unnecessary "trimmings" in the shape of carving, notching, or constructed ornament, and without regard or thought as to its providing inaccessible ledges and resting-places for dirt and filth of all sorts.

Any one about to furnish is obliged, as a rule, to buy the goods that may be in stock, and to make the best of them, without reference to their suitability for any special requirements, and the result of all this is that most modern rooms are very much alike, except that perhaps there may be some distinctive difference in the design and elaborateness of the furniture, according to the means and taste of the purchaser: a dining-room is fitted up with the usual centre table, a dozen or more chairs, and a wall buffet or sideboard fitted with the usual cellaret, trays, and shelves: the drawing-room with various cabinets with elaborate inlays and glass doors, cut and crossed by innumerable bars, so as to prevent the objects of art inside being properly seen, or perhaps fitted with shelves fixed at set heights, but very inconvenient for the objects they are to receive, too narrow or too wide, too high or not high enough: in fact, ready-made clothing for household gods, and, like most ready-made clothing, very often exceedingly ill-fitting, and unsuitable for the wearers. It may be urged that many people do not know exactly what they do want, and are dependent more or less on the upholsterer, or, again, that they want to see specimens of furniture "of sorts" from which to make a selection; that, in fact, they do not know, except in a very general way, what they really want, and therefore are unable to give any idea of their special requirements. In admitting all this, I can only urge the necessity of a higher art-training for the workmen and manufacturers, so that the goods they offer may be more simple, more suitable, and more artistic.

In all furniture, comfort and use should be the first elements in its design; these being given, it should be just as easy to make everything about a house pleasant and artistic in form and design, as inartistic and ugly; a chair, for instance, to be comfortable should have ample support for the back, and be free from all carving and other excrescences, which not only make it uncomfortable, but add considerably to its cost; the seats should not be covered with velvet and other stuffs, which hold dirt and "drag" the dresses of the sitters; the legs should be strong, not twisted or curled, or cut cross-grain, so as to be easily breakable; couches should be made easy and comfortable resting-places, not made so as to offer all kinds of angularities and unpleasant projections.

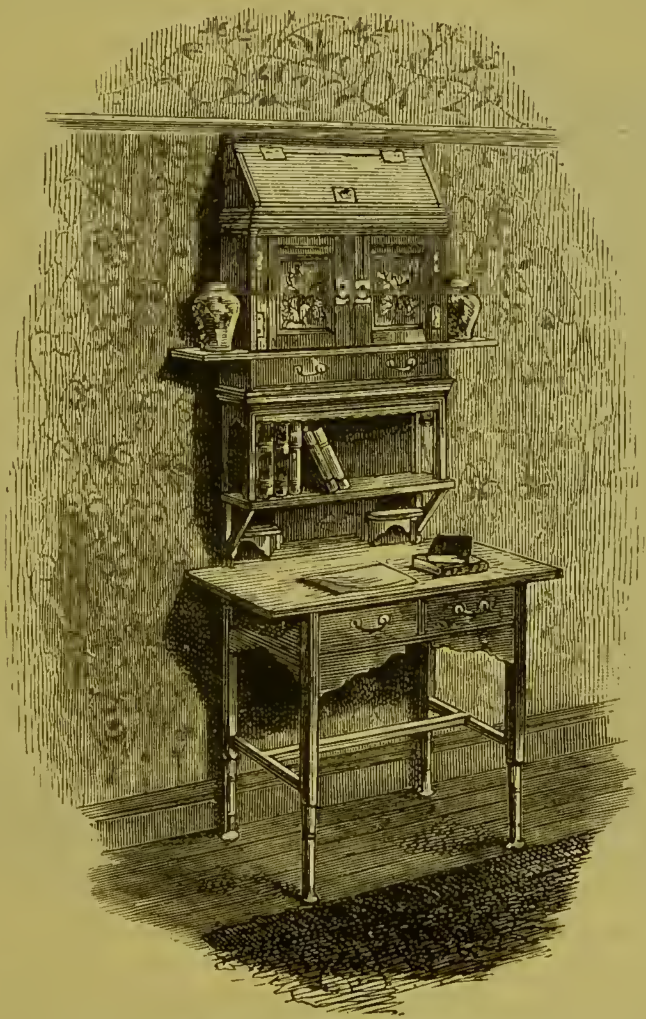
Tables should be so made that the legs do not stand out and catch the knees of those seated opposite to them; buffets may be so designed as to answer for all kinds of purposes, in addition to the ordinary dining-room requirements, with drawers for prints and engravings, shelves for books, cases for china or silver, and cupboards for cigars or tobacco, and be so designed as to form a portion of the decoration of the room.

The ordinary modern sideboard is generally a very useless and expensive piece of furniture, answering, it is true, its purpose so far as to provide a dresser or serving-table, with flanking cupboards for wine and other dining-room paraphernalia; but of what possible use or ornament are the enormous glasses with which these sideboards are generally fitted? Under ordinary circumstances, unless amply provided with lamps or candle-brackets, they do not even light up the room at night, while they form objectionable features in the wall-decoration of any room. A buffet should be an important feature in any dining-room, and should be designed with much more regard for its proper use in ordinary houses than it would seem to be at present.

Let us take an ordinary dining-room of the larger class of the community in this country. As a rule, it is largely used as a sitting, or with the professional man, as a consulting-room; why not, therefore, furnish it as such, instead of in the usual stiff and vernacular manner? In most of our houses the existing arrangement of a large dining-table takes up the greater portion of the room, leaving but little space for circulation. The sideboard at one end is practically useless, except for stowing away wine-decanters and cruet-stands, with, perhaps, one or two drawers for napkins and plate. Treat the walls with warm, quiet shades of brown or red, with the lower dado, of say three feet in height, varnished, with a chair-rail to prevent the chairs chipping the paint, and the frieze painted or distempered in soft yellow or vellum-colour, with stencil enrichment in red, yellow, and greenish blue, or with panels of figure decoration. Instead of the comparatively useless sideboard, have a good solid buffet, that will answer for the double purpose of putting away books, drawings, or papers, and the general dining-room use. This should be made to suit the proportion of the room, and if designed to suit the different requirements of the owner of the house, would be a valuable, instead of, as it usually is, a lumbering addition to the room. A circular table, four feet six or eight inches in diameter, always capable of dining four or six persons, is amply sufficient for all ordinary eating purposes, and for books, papers, and work at other times. Such a table would not crowd up the room, or take away from its comfort and convenience; and made "telescopic," with as many leaves as may be required, it can be enlarged to any length of which the room is capable, and with four end legs set well back, and a strong central support, would be equally strong, open or shut. If made of mahogany ebonised, it can, when elongated for a dinner party, be partially covered at the sides only with "slips," leaving the centre black, on which flowers, silver, or good china will look infinitely better than on the white cloth. The contrast will be pleasant to the eye, and the general effect exceedingly artistic. Let the chairs be simple, but substantial and comfortable. Let the floors be painted, stained, or parqueted all round, say two feet six inches from the wall, and the centre space covered with a good felt or Oriental carpet, warm to the feet, and cheerful to look at. A small rug in the bay window, if there be one, with a simple table—designed with drawers for writing purposes, and capable of being used as a side or carving-table—and a small rug opposite the fireplace, of some good warm colour, will furnish the room. Do away with curtains, which only retain the smell of food and tobacco-smoke, and make the room stuffy and unwholesome, besides hiding light from the pictures and engravings on the walls. The mantelpiece may be made useful as a piece of furniture, with shelves for books, and cupboards for papers or china.

The bed-rooms have the usual chest of drawers, made so deep that you have to turn up three or four suits before you arrive at the one you want to use; or too short to hold shirts and other belongings when folded, or else so long as to leave portions of them useless, unless they are packed with clothes like herrings in a barrel. Doubtless many of these set pieces of furniture can be made generally adaptable for ordinary requirements, but my protest against them is that they are often practically unfitted for their purpose, and wasteful of valuable room. But if the system of furnishing a house with ready-made clothing is to continue, it must, as a matter of course, happen that many persons will be very ill-fitted, even if a few get exactly what they want. Instead of the ordinary chests of drawers,

which for ordinary purposes are extremely inconvenient, we might just as well have the bed-room recesses fitted up with nests of useful shelves or sliding trays made to suit the various requirements of our wardrobes; wide and deep to hold coats and other external garments; narrow and shallow for under-clothing, so that "suits" need not be piled one upon another, necessitating unfolding and displacement of those which are packed on the top of those we want to find; all these



A Bed-room Medicine-case with Writing-table, etc.

could be enclosed by cupboard-doors, close-fitting and rebated to keep out dust, and would, I venture to think, be found much more convenient than the furniture we buy "ready-made."

In the smaller bed-rooms of a house, the wall-surface might be tinted in distemper a warm grey or bluish tint; the woodwork painted a dull blue or dark grey and varnished; the floors painted all over and varnished, with small rugs laid down next the bed and the dressing-table. A small washing-stand might be placed in the corner of the room, with a small chest of drawers well raised off the floor, so as to allow of its being used as a writing-table; the mantelpiece could be fitted up as a dressing-table, with central glass, and cupboard and shelves for brushes and other

dressing paraphernalia; the bed left open without hangings or valences of any kind; a Boyle's ventilator in the chimney-breast, and small apertures for fresh air inlets cut in the sashes; and in this way we should have a healthy and comfortable chamber. The larger bed-rooms might be treated in a similar manner, but with specially-designed wardrobes, hanging cupboards, window-ottomans for bonnets and boots, large dressing-table, with glass down to the floor, swung between nests of drawers for gloves, jewellery, and the other requirements of a lady's room; a medicine cupboard and small writing-table next the bed, and a couch or low chair, so that the room may be used as a private sitting-room, as well as for sleeping purposes, the same principle of ventilation being carried out here as that described for the smaller room. With some such arrangement as this, we might have pleasant, cheery rooms, comfortable and healthy, and, to a great extent, obviate the unpleasant closeness and unhealthy atmosphere which is engendered by occupation at night with doors and windows closely shut.

I hold very strongly that in many cases half the cost of furnishing may be saved by having the bulkier pieces of furniture made to suit the special requirements of the people who are to use them, and that the mass of the general public would find these special pieces more easily adapted to their wants and requirements than the ordinary run of articles they buy ready-made.

If health and comfort are to be considered in furnishing, it must be self-evident that none of the bulkier pieces of furniture should be so made that they cannot be readily removed, to permit of the floor-space underneath being cleaned and washed; or, failing this, there should be sufficient space left open under them for all dirt and dust to be easily seen and removed. If a heavy piece of furniture is made to fix close down to the floor, or open only a few inches under, it must follow that the space below cannot be got at, and that it must necessarily form a resting-place for dirt which cannot be got rid of, and must remain until, at great cost and labour, the furniture is removed for the annual spring or autumn cleaning.

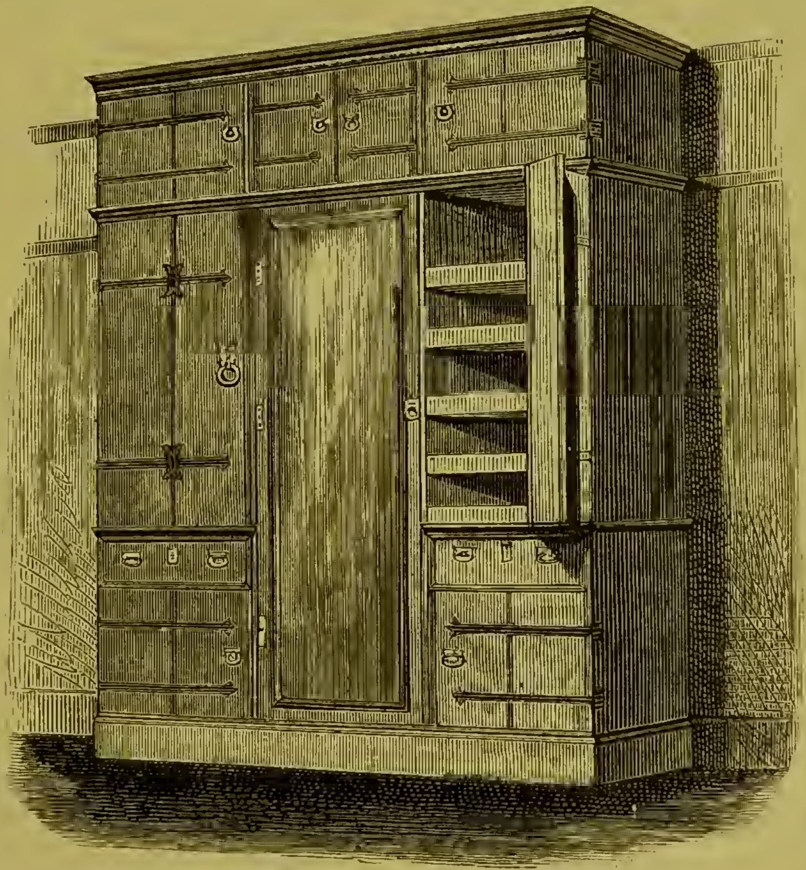
It is very desirable, as far as possible, to have all heavy pieces of furniture arranged on castors, so that they can be easily removed for cleaning or other purposes without risk of damage to walls and floor-surfaces; most people will have experienced the annoyance and labour involved in moving wardrobes or chests of drawers for cleaning purposes, and as a consequence they are too often left *in situ* with all the accumulation of years of dirt and filth allowed to remain beneath them, to the manifest unhealthiness of the rooms.

Most wardrobes, as they are called, and other heavy pieces of bed-room furniture, are made with flat top spaces, which, as a matter of course, become receptacles for dust, which cannot be readily got at and cleaned off; all this dirt cannot fail to assist materially in keeping the rooms stuffy and unhealthy, besides which, much valuable space is thus, to my mind, lost, for the space between the top of the ordinary wardrobe and the ceiling might well be filled up with small cupboards, in which might be stowed away spare linen or clothes not wanted for immediate use. The annexed illustration shows a wardrobe thus furnished, and another will be found at page 342.

In advocating these top cupboards, I have been told that they are inconvenient and difficult to reach; but surely store-places are wanted in every household, in which articles that will not be required for weeks, or perhaps months, may be put

away; and there cannot be any serious difficulty in getting at these top cupboards when occasion requires, by means of a chair, or a set of "chair-steps"—that is, one of those useful contrivances which form a good useful chair and unfold when required into a set of short steps; any way, very few bed-rooms are so high that these top cupboards cannot be easily reached, and I am quite certain that the healthiness of any room will be materially increased by the doing away with all spaces as far as possible where dust and other unhealthy lodgments can take place.

If these top cupboards be objected to as useless, then care should be taken that



A Small Bed-room Wardrobe with Top Cupboards.

the top of the wardrobe or book-case be covered with a ledge of wood fixed slightly sloping, so that the dust can be readily removed by a brush, and this ledge should be polished or varnished to match the piece of furniture, so as to offer a smooth surface with as little holding space for dirt as possible, and be made sufficiently sloping to show from the floor-level any dirt or dust that may have accumulated thereon.

In furniture, as in decoration, there is often much useless extravagance in ornament and material, especially in all bed-room furniture; in this, use and fitness are essentially the first elements to be considered, and I hold that a mere cupboard can be made fair in form and artistic in design with well-arranged panelling and good moulding, without any elaboration of ornament or useless "trimmings" in the shape of tiny balusters and fret-work cornices, and can be just as well executed in deal painted and varnished—the painted surface being made of such a colour as will har-

monise or contrast with the decoration of the room—and at half the cost of French-polished mahogany, walnut, or other expensive woods. Deal and pitch-pine are in themselves sufficiently good for all such purposes as cupboards, wardrobes, chests of drawers, and other similar furniture, and can be left to show the natural grain of the wood by being simply varnished; all this kind of treatment is quite as cleanly and to my mind quite as good as any amount of polish, which requires constant labour and attention to keep clean and bright. The plain varnished woods are light and cheerful, and can be easily kept clean by mere dusting or rubbing over with a damp cloth; strong soap or soda and water should on no account be used in cleaning paint or varnish, for they eat into and destroy it rapidly.

To my mind all modern furniture is, if really good, of infinitely too expensive a character for general purposes, or if cheap is so badly made that it gapes and shrinks, and becomes useless after a few years; this extravagance in common things is probably due to the luxuriousness of the age, which seems to seek after elaboration rather than simplicity in design, and in a great degree to the ignorance and want of taste of the general public, who imagine that good things must necessarily be expensive and that "cheap" things are necessarily "nasty."

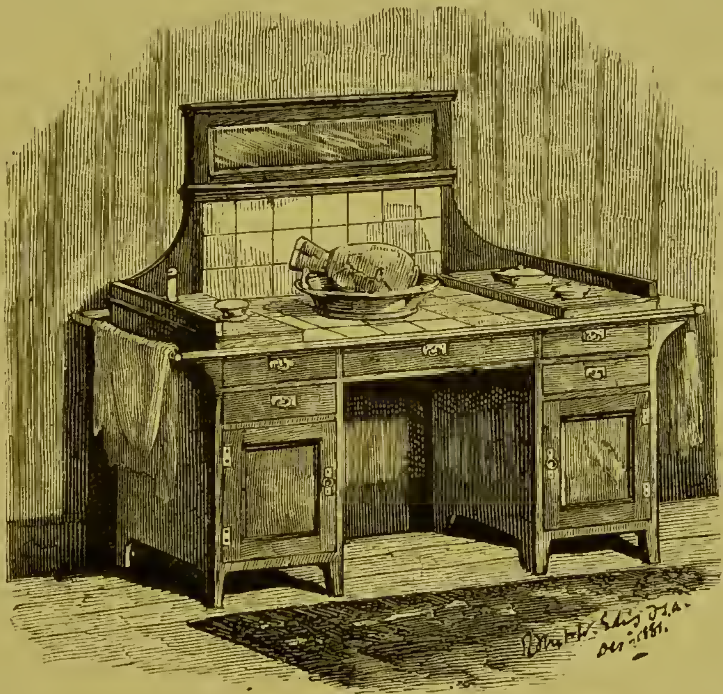
With those who hold these views I have nothing in common. My object is to insist that all furniture may be of good and common-sense design, artistic in form, practical, useful, and good, and yet, compared with the work which is offered to us in most of the ordinary upholsterers' shops, moderately cheap. To my mind painted and varnished deal is just as lasting as polished mahogany, and can be kept clean and bright for half the labour required in polished work; birch and light oak are equally well fitted for bed-room furniture, but are naturally more expensive, although, as a rule, deal is used for the internal fitting-up of most pieces of furniture made of these woods; cedar is too expensive for general use, but is admirably adapted for internal work, as the smell of the wood is said to keep out the destructive little pest "moth."

The so-called "pedestals" are unhealthy and objectionable articles of furniture in any room—placed as they generally are close to the head of the sleeper—and should certainly be dispensed with. The object for which they are provided may be equally well attained by making small cupboards under the washing-stand, and thus removing what must necessarily be an unpleasant and unhealthy feature in the room as far as possible away from the bed. Such a piece of furniture is shown in the illustration on the next page.

Tapestry and stuff hangings, while well adapted to take off the coldness of unplastered walls of mediæval buildings, are quite as unsuitable as their humbler imitations in the shape of cretonne and chintz, for the wall-coverings of modern rooms in thickly-populated cities and towns.

The carefully closed-in beds of the Middle and Renaissance Ages might have been necessary in the large and draughty rooms of our forefathers, but are unhealthy and unsuitable for modern rooms, in which pure air and absence of stuffiness can only be obtained by carefully abstaining from the use of anything that prevents free circulation of air and ventilation; for it must be remembered that only by this free circulation of air and constant ventilation can the rooms be kept free from the moisture which clings to all wall-surfaces, whether papered or distempered, and which is so fruitful a source of discomfort and disease.

The bed-rooms of a house should be kept as free as possible from all useless hangings which impede air circulation; the furniture simple and useful, well made and dust-tight; the floor-surface left free all round the walls and under the bed and wall furniture, and carpeted only so far as is necessary for comfort; all ledges and resting-places for dirt should be carefully avoided, such as Venetian blinds, valences to beds and windows, and inaccessible shelves; the fire-places left open, not closed up as is often done in the summer-time with curtains and useless hangings; the woodwork polished or varnished, so as to be easily cleaned; and the walls covered



A Small Washstand with Pedestals.

with simple pattern papers or distemper, so as to present no spotty surfaces for the eye to rest upon.

Bed-room furniture can, to my mind, be materially improved by being more compressed, and by much greater use being made of the recesses formed by the projection of the chimney-breasts; all these can be fitted up at moderate cost with useful hanging closets and drawers, while the mantelpieces of ordinary bed-rooms may be rendered into useful articles of furniture by being fitted with side cupboards, shelves, and drawers, so as to form dressing-tables. Washing-stands should be of the simplest possible construction, fitted up with tiles to a height of eighteen inches or two feet at the back, with as little woodwork as possible to get wet and dirty; the sides can be formed into useful cupboards with racks or pegs for boots—generally difficult articles of dress to stow away comfortably; while the centre might be fitted with a zinc receiver to take off the waste water, this receiver being made immediately under the basin, with a place to allow of the dirty water being easily emptied into a pail, and with ample access for thorough scouring and cleansing; a glazed earthenware trough is better than any metal-work, as being less likely to hold grease and dirt, and more easily scoured; but all these

receivers must be so made that they can be readily accessible, or they will become foul with soap and dirt, and soon smell sour and unhealthy.

Every piece of furniture should be fitted for its purpose, truthful in design and material, and not pretending to be something else, or made of some other material. It may be a small matter, but what earthly use is it to grain one wood in imitation of another, or to paint the inside of tin baths in imitation of marble? Not only is all such false work a sham and a lie, but it is bad in taste, and infinitely more expensive than plain painting or enamelling. It may be absurd to say that truth in such small things is just as essential as truth in anything else in daily life, but surely anything that pretends to be what it is not, and seeks to delude the eye by false imitation of something else, is as immoral in its tendency as what are called "white lies" are in general life; shams and unrealities are but lies, equally to be avoided in the things we surround ourselves with as they are in daily life.

All such shams and pretentious deceits should be repugnant to all morality, as they are utterly at variance with all good taste and real art. They may deceive no one, for I suppose few persons would conceive the tin bath to be marble or the grained cupboard to be really what it pretends to be, but under any and all circumstances they are shams, bad in taste, bad in art, and bad in every moral sense. Little lies very soon lead to bigger ones, and those who are content to see about them small shams of the kind I have mentioned will be equally content to see floor-coverings in imitation of marble, tiles, or inlaid woods, wine-coolers made in the form of sarcophagi, and other work equally bad in art as in taste. What can be more trashy or commonplace than covering walls with imitation marble or tile papers? At their best they are cold and formal, and utterly unlike the real thing; good marble and well-coloured tiles are pleasant objects to look upon, but their false imitations are not only painfully unreal, but entirely opposed to all good decoration; nothing can be worse in general effect and tone than a staircase wall covered with sham marble blocks, and nothing more useless as a protection against water than a bath-room lined with paper in imitation of painted tiles.

If you are content to teach a lie in your belongings, you can hardly wonder at petty deceits being practised in other ways. Teach truthfulness at least in the things with which you surround yourselves, and avoid shams and deceits of all kinds, resting assured that real colouring and real work of all kinds is infinitely better, quite as lasting, and infinitely cheaper than sham graining, marbling, or gilding; at least be honest in decoration and furniture, and do not add the vulgarity and pretentiousness of unreal work to badness of taste and trashiness of construction. As a rule, all this kind of sham is suggestive of trumpery materials, for with really good things imitation and deceit are out of place and unnecessary; all this carrying into every-day life of "the shadow of unreality" must exercise a bad and prejudicial influence on the younger members of the house, who naturally are thus brought up to see no wrong in the shams and deceits which are continually before them, and do not understand the badness of taste, not to say morality, which there is in making our "domestic surroundings appear something which they almost manifestly are not." I am quite aware that I am laying myself open to being called absurd and utopian in setting forth such doctrines: that marbling the inside of a bath,

or graining deal to represent oak, or painting floor-cloth to represent encaustic tiles or parquet-work, and putting up paper in imitation of painted tiles or marble blocks are only other forms of decoration quite as good as painting "Queen Anne" blue, sage-green, or any other fashionable colour.

It is impossible within the limits of an article of this kind to discuss, or even passingly allude to, the numerous modern inventions which each year brings forth for the greater comfort and convenience of house fittings and furnishing: the exhibitions which take place almost annually of building appliances, furniture, and sanitary arrangements, offer to the public constant opportunities of seeing and adopting, if they will, the many improvements that are taking place in house decoration and furniture; the reviews and criticisms on these in the public press are generally fair and exhaustive, so that those who are unable to judge for themselves as to what are really improvements, may ascertain from these what to use and what to avoid.

In a recent Building Exhibition at the Agricultural Hall, and in the Exhibition of Furniture at South Kensington, there were many valuable suggestions offered for the improvement in art, comfort, and cleanliness of our dwellings; almost every magazine and daily paper has treated more or less exhaustively on the subject, and there is no reason why, with the narrowest means and in the humblest of abodes, good art in form and colour may not be combined with comfort, healthiness, and, to those who will, luxuriousness of furniture and decoration. In the present craze for novelty, practical common sense is often lost sight of, but there is no real reason why our homes should not be made artistic and beautiful, and at the same time healthy and comfortable; if we will but have care to avoid, as far as practicable, all those things which gather dust, tend to retain smells and other impurities, and to remember that decoration and furniture which might have been fitted for spacious rooms and lofty halls, are not at all suited to the often close and stuffy rooms of modern dwellings.

It is impossible to more than passingly allude to gasaliers and the other smaller articles of furniture in a house. The simpler all these are the better. Gasaliers should be of bronzed brass in preference to lacquered work or iron. The lacquer soon gets tarnished, and the iron is liable to rust by the damp and decomposing products of gas. Gas tends to destroy everything in our rooms, to render them hot, stuffy, and unhealthy; and unless a constant supply of fresh air can be brought into them, it is well to burn as little gas as possible, especially in the sleeping-rooms of the house, where the foul impurities that are given off by gas, together with the enormous amount of vitiated air formed by the products of combustion, make the rooms filthy and unhealthy.

In the cheap speculative houses the door and window furniture is often of the most trumpery as well as the most inartistic description, and is an endless source of annoyance. The best and simplest furniture that I have seen for ordinary doors is that known as "Kaye's" percussion lock and furniture, which, so far as I can judge by the experience I have had of it, is not likely to have the handles constantly coming off, or be otherwise getting out of order. If the doors be varnished, finger-plates are unnecessary, and if used should be of the simplest possible character. Several eminent manufacturing firms now make some exceedingly artistic glass candle and gas brackets and chandeliers, which are fitted for

almost any room where good artistic effect and simplicity of design are required. The beautiful Venetian glass-work, with its modelled flowers and leaves, is somewhat out of place in ordinary houses, as the dust works up under the ornament in places which it is difficult to clean, except by taking the work to pieces.

With all the vast improvements that have been made in the various trades concerned in the decorating and furnishing of houses, and by exercising the same common sense and common care as in other matters of life, by a careful regard for use and suitability, and an avoidance of all that is false and meretricious, we may make the homes we live in not only comfortable and healthy, but artistic and beautiful.

CHAPTER XXXIV.

INTERNAL DECORATION AND PURE AIR.

Dust means Disease—Evils of Curtains, Waste Papers, and Lumber—Ventilating the Hall—Decorative Ventilation—Cleaning—Disposal of Refuse.

It may possibly be argued that it is a matter of small importance how the wall and floor-surfaces of our rooms are covered, so long as they are warm and comfortable, and that it is a matter of indifference what may be the especial artistic design of the furniture we use, provided it be fitted for its purpose; and that the moral and healthy aspect of our homes is not to be improved or impaired by any particular treatment of decorative design or arrangement of the furniture and fittings of the particular rooms. If, however, as it must be admitted, dirt and impure smells act prejudicially upon us, and tend to ill-health, nausea, or bodily lassitude, it is especially essential that as much regard should be paid to the proper covering of our floors and walls, and to the furnishing of our rooms, as to drainage and ventilation. All papers which hold dirt, and all materials which absorb and retain impure smells, should be avoided, and no furniture should be placed in our rooms which in any way holds dirt and dust that cannot be easily seen and cleaned away, or which allows both to accumulate under it in places which cannot readily be got at; for if a room cannot be made thoroughly fresh and clean in every part by every-day washing or dusting, it must be manifest that the atmosphere in the room—although perhaps imperceptibly—must be charged with minute and invisible impurities, which are unwholesome and unhealthy.

For this reason I would, as far as possible, do away with stuff curtains, fluffy and looped-up lace or other similar blinds, with flock raised papers on walls, and with all high ledges or shelves, where they cannot readily and easily be got at for cleaning purposes.

If there be any truth in the assertions that are made that nausea and general lassitude, not to speak of any severer forms of illness, are engendered by want of attention to the proper healthy arrangement of our homes, and that dirt and dust are to a certain extent equally conducive to the unhealthiness and unwholesomeness of our houses as defective drainage and bad ventilation, it must be admitted that we have yet much to learn for the more practical and better fitting up of the rooms we live in, and that too much care cannot be exercised in providing that, so far as practicable, all extraneous and useless ornaments and unhealthy fittings shall be avoided. Many people litter their rooms with all kinds of lumber, until there is hardly a corner free from it. They cover their floors and tables with fluffy mats of various kinds, which hold all kinds of dust and dirt, and which, like pitch, you cannot touch without being defiled. With the best of servants and the best of supervision it is impossible to keep such rooms pure and wholesome. Things stowed away in all sorts of odd corners, wherein they are left undisturbed for months, must breed dirt and disease; and while it is, of course, necessary that in every household there should be storing-places for all sorts of things only required for a season, and

then to be stowed away, such kind of storing-places should be made suitable and convenient, so that they can easily be got at and easily cleaned.

It is possible that there may be some sort of sentiment existing which makes mothers desire to keep for all time the long-disused toys belonging to their children in early life, and I have seen boxes and cupboards half filled with broken toys and other useless lumber, which only serve as resting-places for all kinds of impurities, —seldom disturbed and rarely cleaned out—while in our hospitals and amongst our poorer neighbours, there are hundreds of children who would be delighted with these no longer required toys and belongings of our own childhood. Clear out all such lumber, and give all that is fit for anything—old picture-books, old toys, old clothing —to those who will heartily appreciate them; and while conferring a pleasure on these little ones of our poorer neighbours, who cannot possibly obtain in any other way such things as toys and picture-books, you will be clearing away things which are now only lying useless in some out-of-the-way corner or cupboard, and adding to the comfort and cleanliness of your own house.

How many thousands of poor children are there who would be benefited and amused, and whose lives might be made more cheerful and more happy, by the contents of many a box or cupboard of toys and books which are no longer required! Every housewife knows how old books, old papers, old clothes, old linen accumulate in the course of a few months. Instead of these being periodically cleared out and given away, they are often carefully stowed away in the most out-of-the-way places, practically as useless, and help to make the rooms and house generally stuffy and unhealthy, when they might be the means of giving health and pleasure to others who have no means of purchasing them for themselves.

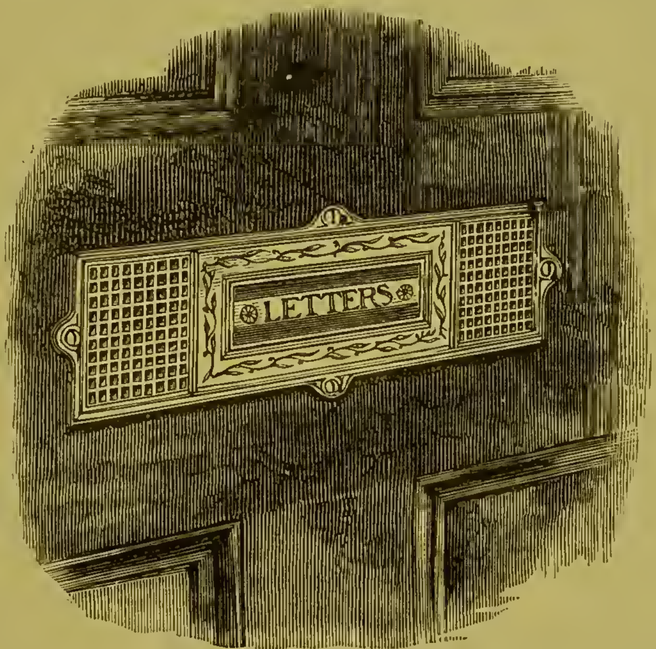
Again, in offering suggestions for the healthy and artistic treatment of the bed-room and nursery walls, it must be borne in mind that they are all comparatively useless without some proper system of ventilation, for, to quote Captain Galton's invaluable little book on "The Construction of Hospitals"—"the purity of the air within an inhabited space enclosed on all sides, is necessarily vitiated by the emanations proceeding from the bodies of those who inhabit it, and especially by the effect on it of their respirations." With persons suffering from disease, especially infectious fevers, or from wounds, or sores, these emanations are greater in quantity, and more poisonous in quality, than from persons in health. Stagnation in the movement of the air leads to rapid putrefaction of these emanations.

The oppressive and unhealthy atmosphere of an ordinary passage-hall, where gas forms the principal means of lighting, is very discernible after the house has been lit up for a few hours. The bad air and heat engendered by the gas stifles, as it were, the real lungs of the house, and adds materially to our discomfort. I have designed a simple but effective means of remedying this to a great extent, by forming small zinc tubes on each side of the letter-box, with open tops and valves, and with gratings on either side of the usual letter-box flap externally, so that there is a constant current of fresh air entering the hall, without draught, and purifying and mixing with the heated and foul air, thus rendering the atmosphere more healthy and pleasant. The illustration shows its appearance from the outside.

In ordinary sitting-rooms there is a constant influx of air from doors and windows, and practically the rooms are never shut up for any great length of time

without being in a measure swept out by currents of air thus admitted; in winter-time the fire acts as a constant extracting power, and without any definite system of ventilation there is not, under ordinary circumstances, much difficulty in keeping a sitting-room fairly well ventilated.

Much may, however, be done to improve the atmosphere of these rooms either by the use of what are called "Tobin's" tubes, or by cutting the meeting-bars of the ordinary window-sashes, so as to bring fresh air into the room; for it is quite certain that without the means of bringing a constant supply of fresh air into the room, to



VENTILATING LETTER-BOX.

push out and improve that which has become foul and vitiated, no real comfort can be obtained in any room after the house is "shut up" and the gas lighted. The rooms then become hot and stifling, engendering headache and nausea; and if the windows be opened, draught and possible cold negative the good result that might accrue by the access of fresh air. These so-called "Tobin" tubes are generally obtrusive and unsightly objects in any room, put up without thought of any kind as to the arrangement, so that a good many artistic people are content to put up with stuffiness of atmosphere rather than spoil their rooms by square or circular pipes stuck up in one corner, and looking very much like cut-off stove-pipes.

There is no reason why this scheme of ventilation should not be incorporated in the design of some piece of furniture, or made sightly and artistic one way or other: the pipes might be made of terra-cotta as ornamental angle pedestals with projecting lips, or shelves on the top to take small busts, vases, or bronzes, without impeding the circulation of the air; or the tube can be brought under the floor to the fireplace and be incorporated in the design for the mantelpiece, or in the uprights of a fixed bookcase or cabinet, so long as the air-tubes have a sufficient sectional area of, say, from about fifty to sixty inches—that is, a measurement of eight by six or ten by six inches, according to the size of the rooms. They may be

made to any form. As a rule, two of the smaller-sized pipes will be desirable for an ordinary-sized London dining or drawing-room. The tube itself might be finished with a terra-cotta pot, out of which the bottom must be cut, or with an enamel or other vase, much in the same way as they are used for lamps, except that the bottom must be open, not closed. There are innumerable ways in which to introduce fresh air into a room without making it unsightly, but, like everything else that is done well, the means and design must be thought out and adapted for each particular room and place. Sometimes small flat square tubes can be fixed next the projecting window architraves, and finished with a small moulding at the top, with the skirting moulding carried round so as not to be unsightly; or they can be arranged so as to be hidden by the curtains, which in most rooms are fixed to the window boxings or architraves, projecting several inches into the room and leaving ample space behind for the air-tubes.

Mrs. Priestley, a lady who is well known for her efforts in the cause of hygiene and sanitary science applied to domestic purposes, has had registered an extremely efficient and simple contrivance for the ventilation of rooms, which is at the same time very pretty and decorative, and can be made with a little care highly artistic. This "Floral Art Ventilator," as it is called, consists of a glass box or case, which stands upon a table, and fits into the window opening to about half or two-thirds of its height, the portion next the window being open, the sides made of looking-glass or tiles, the bottom formed to receive flowers, and the front next the room being made as glass casement doors, for access to the flowers or to the external sashes; the top is left open, so that when the lower sash is opened there is a good current of fresh air which finds its way upwards into the room without creating any perceptible draught. The current of air being thrown upwards, as in "Tobin's" tubes, causes it to mix with the air of the room, and thus materially improve it without the unpleasant effects of an open window. By means of screens next the open sash and above, strained over with gauze, the "blacks" and dust are kept out, and the body of fresh air admitted to the room can be controlled at will, according to the height to which the outside sash is opened. This ventilating-case is made to contain flowers and ferns, so that the general appearance is extremely pretty and decorative, while the result as regards ventilation is eminently satisfactory, the air in its upward progress being filtered and moistened by passing through the flowers and ferns below. This filtering process, by means of the plants, takes off the "ammoniacal and carboniferous impurities," to quote Mr. Seymour Haden, with which the air of large towns is so materially laden, and the picturesque and graceful appearance of growing plants is made to assist the purity and healthiness of the room.

There are many simple and effective means of providing fair ventilation without discomfort, and in conjunction with the decoration of the rooms; amongst others I would suggest as the simplest means of bringing in fresh air, the use of small upright shafts or tubes in the angles of the rooms, communicating with the external air, and provided with simple regulating valves; gratings over the door-openings leading to the staircase wells, the inner grating being fixed at a much higher level than the external one, so as to prevent down-draught as far as possible; these gratings are, I know, objected to often on the ground that they admit and let out sound, and are, to a certain extent, productive of draughts.

Much more might be written on this subject of ventilation, were the subject not to be treated specially hereafter. My object in briefly alluding to it is to insist that it should form a part of the practical decoration of every sleeping-room, and that it may well and easily be incorporated with the decorative treatment of any room.

Curtains and ornamental blinds are generally quite unnecessary in any house if a little thought and care be taken with regard to the general decoration and arrangement of the rooms. These hangings naturally hold dirt, and where there is dirt there must be disease. In the bed-rooms dark blinds will effectually shut out light, and in the sitting-rooms use should be made to a much larger extent of coloured glass, of good and harmonious colouring, by which a soft pleasant light may be infused into the rooms, and a protection be obtained from the glare of sun-light. Roller-blinds must still form part of the window furniture, but let these be of some glazed material and not of the fluffy frilled stuffs that are now becoming fashionable; all these kind of things hold dirt, get dusty, soon want changing, and are necessarily expensive and objectionable. Everything about the house should be made useful, all ledges and unnecessary dust-spaces should be carefully avoided, and everything so arranged that it may be easily cleaned with as little labour or trouble as possible; all furniture which has superfluous carving or moulding should be avoided, and simplicity, utility, and common sense should take the place of the excessive ornamentation with which much of the modern type of furniture is over-laden, to the detriment of health and the loss of money. There is no reason why we should "convert our homes into pest-houses by a style of furnishing which renders accumulations of filth not only likely but positively inevitable."

It may be said that curtains tend to the comfort and warmth of a room, and therefore cannot be done away with. If they must be used, let them hang straight down in natural folds from a light painted iron or brass rod, and not be "draped" or "looped" up so as to form lodgment spaces for dust. When pulled across the window they will answer all the purposes of keeping out light and draught, and can be easily brushed down, whereas if "draped" up, a portion rests upon the floor when they are drawn over the windows at night, and collects and retains dust. All fringes and valences should be avoided for the same reason, as well as from the fact that they are utterly inartistic. If the wall-space be divided, and the upper portion treated with painted or distemper decoration, and the woodwork of the window treated properly as a framework to the light or glass surface, curtains will only damage the artistic effect, by cutting up and interfering with the ornament and design of the frieze. In a dining-room, they naturally absorb and retain the smell of food, and tend to make the room stuffy and unhealthy; and, for the same reasons, they should be, as far as possible, avoided in the sleeping-rooms of our house. It is impossible to get rid of the smell of tobacco-smoke in any room where curtains are used, as after a time the material of which they are made becomes practically saturated, and the stale, unwholesome smell becomes almost as bad and unbearable as that which all travellers must have noticed in the smoking carriages of railways where they are lined with cloth or other absorbent material. It is not necessary that the architrave, or enframing moulding of the windows, should be left perfectly straight: the upper portion may have some small central designed

ornament, or the decoration above the moulding may be so treated as to take off from the square effect of the opening.

Clean out as often as possible every room and every cupboard in the house, give away anything that is fit to give away, which may no longer be required by yourselves, and burn or destroy all other litter and lumber, which are only resting-places for dirt and dust, and living impurities which grow out of dirt and dust.

The National Health Society is doing good work in promoting all matters which tend to improve the sanitation of our dwellings, and although the following remarks on the removal of dust may not strictly come within the limits of this article, yet the nuisance and damage caused to our rooms and everything within them by the weekly stirring-up or "removal" of the refuse and ashes from the dust-bin is so serious, that I do not hesitate to insert here, and heartily endorse, a suggestion of Mrs. Priestley's for rendering this weekly scourge as small a nuisance as possible. Who has not experienced the nuisance which Mrs. Priestley describes, in the heat of summer, when doors and windows are open, of the nauseous odours which rise up from the cellar or out of a dust-bin, into which "everything filthy and decomposing is thrown, and allowed to lie unheeded," only to be aggravated by its weekly or bi-weekly stirring-up and removal, when the dust and filth are scattered broadcast everywhere, and in its descent to the dust-cart sends up a stream of foul dusty vapour, which is blown into the house, to the manifold detriment of everything with which it comes in contact, and of our own bodily comfort and health? Mrs. Priestley suggests that this serious evil can be reduced to a minimum by doing away entirely with all dust-bins, and substituting open-mouthed sacks hung up in one of the area cellars by means of small hooks across two light iron rods fixed parallel, about twelve inches apart. Into these sacks the servants can readily empty the dust and ashes, and the dustman has simply to loop up the sacks when full and carry them to his cart, with comfort to himself and every one concerned. The man himself is thankful to be saved from the dust-vapour, which compasses him in every way under the old system and seriously affects his health, and is glad to take the slight extra trouble requisite in returning the sacks—of which, of course, two sets must be provided. The sacks can be obtained for 2s. each, and the rods can be fitted up at a trifling cost. The London vestries will do well to urge the general adoption of Mrs. Priestley's valuable suggestion for remedying a very serious nuisance and evil. The kitchen refuse can be kept in a large covered pail and removed every day, for if kept and allowed to decompose it must inevitably breed disease and discomfort.

CHAPTER XXXV.

ARSENIC IN WALL-PAPERS AND PAINTS.

BY MALCOLM MORRIS, F.R.C.S.E.

General Adulteration—Arsenic Prohibited Abroad—Arsenical Poisoning an Actual Fact—Difficulty of Proof in some cases—Nature and Extent of the Evidence—Simple Test for Arsenic.

JOHN BUNYAN, in his "Holy War," which Macaulay has eulogised as a "miracle of genius," has depicted, in quaint but graphic language, the assault and capture of the once flourishing town of Mansoul. We are told that of the besieged garrison the first to be disposed of was one Captain Resistance, who succumbed to a shaft from the bow of Tisiphone, and that, deprived of his services, the town shortly after surrendered to the victorious Diabolus.

The sequel is a gloomy picture. The town speedily yields itself a prey to artifice and deceit, and under the reign of the tyrant loses all trace of its former purity and peace. If the "indulgent" reader, as it was once the fashion to style him, will not be too hypercritical, I think this grand old allegory may, with a little adaptation, be made to illustrate the present condition of one of the not least important questions affecting the welfare of the community: viz., Adulteration.

If for "Resistance" we read Self-preservation; for "Tisiphone's Shaft," Inertness; for "Artifice and Deceit," Adulteration and all occult noxious influences; for "Diabolus," the enemy of souls, Disease, the enemy of bodies; for "Purity and Peace," Physical Health and Happiness; and for "Mansoul," England—I do not think we shall be much overstating the gravity of the situation.

To drop metaphor and come to the point: Is not the national life being sapped by the wholesale traffic in adulteration, and by the toleration of remediable evils of all sorts? To the latter I shall have more particularly to refer presently. But in the first place, I would ask, with all earnestness, What does it avail us to have "Our Homes" healthy, if the food we eat be robbed of its life-sustaining properties? Our legislators awoke, in a measure, to the gravity of the consideration in 1875, when an Act was passed making the adulteration of food a penal offence. But this did no more than touch the fringe of the great questions of hygienic reform. We must literally look nearer home, the Englishman's boasted castle, and see what legislation has done for that. What have the sanitary inspectors done? Here is a little rule-of-three sum: If a prince for the outlay of about £40,000 obtain a house that is practically little better than an ornamental sewer-gas factory, what sort of pest-house may one expect to rent at from £50 to £100 per annum? And here is another: If adulteration of food, hedged about as it is with stringent laws, thrives—as it assuredly does—in spite of the periodical prosecutions one reads of from time to time in the press, what, think you, is likely to be the extent of similar mischief, in a branch of the same business with which the law does not meddle? I refer to the wholesale poisoning of articles of dress, wall-papers, paints, &c., which more immediately affects the question of "Our Homes, and how to make them Healthy."

It is almost inconceivable that here in England, where so much has been, at all events attempted, with a view to restricting the introduction of deleterious ingredients into articles of food, the wholesale employment of arsenic in the colouring of many descriptions of wearing apparel and household furniture should be recognised and tolerated.

Prussia, long years ago, set us an example, by prohibiting the sale of all articles coloured with arsenical pigments. Bavaria, as far back as 1845, imposed like restrictions. France will not permit the sale of arsenical wall-papers. Sweden, in 1879, passed a stringent decree against them. But England, as yet, has proved a far too sacred soil for any such radical process. The fact is, we do not as a nation take kindly to paternal government. We like to think and act for ourselves, and at first blush it does look as if by discarding arsenic we should deprive ourselves of some of our best colours. But this is not the case. Æstheticism need "moult no feather," for although within my knowledge many of its colours contain arsenic, it is by no means an essential to their beauty.

The rejoinder of the Protestant to the Catholic priest, who cynically inquired where his religion was but a few centuries ago, "Where was your face before it was washed?" precisely defines my views with regard to all these injurious pigments. Manufacturers are not dependent on deleterious ingredients by any means. It is well known that the most beautiful and delicate tints can be produced without employing one single grain of arsenic. Colours the most chaste and perfect existed before ever men sought for arsenic. We adapt ourselves to circumstances very readily. The proverbial "mother of invention" can scarcely be more propitiously invoked than to aid us in searching for that which shall render the useful and the beautiful alike innocent as well. But has any one attempted "to wash the face," so to speak, of these objectionable pigments? Yes; and successfully. First, however, before mentioning remedies, let me endeavour to indicate the disease. And I will begin by saying that danger is lurking at the present moment unsuspected in many a home, and that *it is no uncommon thing for men and women to die, poisoned by arsenic in a wall-paper.*

The reader's smile of derision can be imagined as he reads these words. He has lived, he says, for years with his walls hung all over with the brightest of greens, and yet he is alive. Well, that we will not be so metaphysical as to doubt. And he is in good health, for aught he knows. But if ever he should be ill, let us remind him that he will suspect none but known causes. Like Hotspur's wife, "you cannot utter what you do not know." Our knowledge is very limited, even now—the physician's as well as the patient's. What, then, if the cause he seeks whereby to account for his ill-health should lie outside the domain of intuitive domestic economy, and even also evade his doctor's practised eye? What if Nature, our great schoolmistress, who teaches us wisely by littles at a time, be but now admitting us to a new fact, a fresh lesson in the jurisprudence of self-preservation? Let us see if it be so. And since all we know to-day was once new to the world, let us be very careful how we receive her tuition, for she wastes no words on us, and if a hint be all she deigns to give, let us be grateful even for that.

From the somewhat obscure nature of questions of this kind, it is very difficult to deal with them in an attractive or popular way. Still, the point to which we desire to direct attention is of such vital importance, that prominence ought to be

given to it in a work on "Our Homes, and how to make them Healthy"; for surely no home has any claim to be considered healthy so long as a subtle poison coats its walls and contaminates its air.

First, then, it behoves us to examine the truth of the assertion that people suffer materially in health—sometimes die—from the effects of arsenic imported into wall-papers or paints. And if I fail to prove my case to absolute demonstration, I shall at any rate be able, I am convinced, to adduce such sufficient evidence of a circumstantial character as will lead my readers to act with caution, and pending fuller testimony—which will be soon given to the world—to shun, as they would a fever infection, all articles admittedly containing arsenic.

One question will be asked at once: How am I to distinguish that which is dangerous from that which is harmless? And here we are met by a difficulty. There ought to be no element of doubt in the matter. If our sanitary arrangements were on a par even with our system of police (and that is not putting the standard very high), discrimination ought to be unnecessary. A mere suspicion of mischief brewing, the apparent intention to commit a felony, justifies a constable in apprehending the suspected person, and a magistrate, if need be, in consigning him to prison, prevention being considered better than cure.

Not so with wholesale poisoning. Each sufferer must judge for himself, and, worse than all, when the iniquity is discovered there is no penalty meted out for the offence. As the law at present stands, we cannot punish the poisoner, nor can we prevent his disseminating his poison. The law does not interfere.

But this is no reason why, when we have found him at his deadly work, we should voluntarily make ourselves his victims. Indeed, some of the manufacturers of these injurious pigments, counting on the ignorance that exists as to the harm their goods are working in the community, make bold to acknowledge the admixture of this noxious agent. All we can do is to use the evidence—often dearly bought and scantier, it may be, than we could wish—which tends to point to arsenic as the only explanation of the otherwise mysterious coincidences that occur constantly in connection with cases which, from their peculiarities, have baffled all other solutions.

There are a certain number of people—and their number is daily increasing, we find, as we look more carefully into the subject—who suffer chronically from ill-health of a kind most difficult to describe; in some cases trifling, perhaps, but still chronic. No cause at all is assigned to their ailments. The mischief is laid at the door of a variety of things having nothing whatever to do with it. This is an every-day experience. The nature of a man's occupation is blamed, or over-work is said to be at the root of the morbid condition; anything, in fact, but the real source of the evil. Change of air is recommended as a remedy, with marked beneficial results. All the credit is given to the bracing air of the place visited (justly, in a sense), and to the rest from work and freedom from anxiety. Nothing is said about the removal from a special condition of contaminated air. Of course, we do not pretend that all cases such as these are ascribable to arsenical poisoning. In these times of fast living there must be periods of relaxation. But what we want to urge, and that strongly, is that when a relapse takes place after the return home, and some of the now well-understood indications occur to put the doctor or patient on his guard, and to lead to the suspicion of the cause we have named, such broad hints should not be lightly set aside.

The only safe way to test the question is for the patient who is suffering from a more or less chronic disorder, the nature of which is doubtful, to submit to the experiment of alternately living in, and then avoiding for a period, the suspected room. Should the symptoms entirely disappear, or even greatly improve, while he is away from, and re-appear or increase in severity on his return to, the room usually occupied, it is a strong argument that there is something in the room which produces the change.

Well, then, let us see what are the symptoms of arsenical poisoning by wall-papers, &c. Are they easy to recognise? or do they simulate other diseases? Undoubtedly they do; hence the difficulty. Arsenic is largely used, and has long been employed internally as a powerful remedial agent in ague and diseases of the skin, and in some cases it is administered with good effect in very considerable quantities. But the effects of an over-dose differ materially from those observable in the process we are considering. When taken intentionally, it is a well-known fact among doctors that individuals can acquire the habit of taking large doses of arsenic without its apparently producing any effect. And before we proceed to consider the various groups of cases of well-authenticated poisoning by wall-papers, it will assist us to review some of these phases of its action. One of the best examples of its free and unrestricted application occurs among the Styrian peasants. It is used by them to improve their personal appearance, and also to enable them to breathe better. The men regard it affectionately, much as we do tobacco—not as a narcotic, however, for it is not that—but rather for its tonic properties. They think it increases their strength, assuages their troubles, and makes them capable of carrying heavy loads at high altitudes without fatigue. As much as four grains has been known to be consumed by one of them at a dose. The women, too, employ it to give brightness to their complexions. So that it is credited with the powers of conferring both strength and beauty.

In England it is given to improve the appetite of the horse, and render his coat sleek and glossy. It was so employed by a groom at Balham, and the coincidence of his master dying from poison at first led to curious complications.

When given as a medicine, arsenic acts as an important nervine tonic. Its action is well known, so that physicians administer it over long periods and in increasing doses, not only without bad, but with decidedly good results.

These are facts which make those who give arsenic as a remedy, sceptical when they hear it asserted that even a comparatively small quantity of the metal, if mixed with the pigments of a wall-paper, or forming one of the ingredients of a paint, may give rise to serious and dangerous symptoms of poisoning.

As a rule, the first sign of poisoning, when the arsenic is taken by the mouth, is pain at the pit of the stomach, which becomes worse on taking food; then the eyes become affected, the lids swollen, the whites appearing inflamed and red. There is also much irritation and dimness of sight. After this, if the poison be of sufficient quantity, graver symptoms arise. Diarrhœa sets in, accompanied by sickness, cough, and spitting of blood; the hair and nails fall off, and finally the patient sinks from exhaustion.

The amount of arsenic that can be taken by an individual with impunity varies enormously. Some people are particularly susceptible to its use. Then again, the too rapid increase of the dose has much to do with disturbing its beneficial action.

From want of care in prescribing, it has come to be considered more dangerous than it really is when judiciously handled, and has obtained the ill name of a cumulative poison. The mucous membrane, upon which it acts, needs to be steadily watched, and the outer coat of the eye gives an unfailing indication of the moment at which it should be discontinued. Of course, the idiosyncrasies and peculiar temperaments of different people make the study of the application of this, as of many other medicines, very difficult; and just as they are susceptible or otherwise to its administration in one form, so will they be affected by it in another. This is often overlooked. People have frequently told me that they themselves live in rooms papered with palpably arsenical papers, and that they still enjoy good health, and do not intend to have them removed. My answer to this is, that either they do not occupy any particular room for long together, or they belong to that fortunate class of persons who can take arsenic with impunity. To give an instance, it would be clearly absurd to expect that a sporting man, or one with out-door tastes, should suffer if his study were covered with the brightest of bright green papers. If he were to visit an arsenic factory as often, he would take no harm. It is those who live in, who use their rooms, who ought to be protected from what has been not inaptly termed the "devil's dust."

The most dangerous because the most generally used preparation employed in wall-paper printing is the trioxide of arsenic. We find it largely in what is called "Scheele's green." Then there is the emerald-green, an aceto-arsenite of copper, for producing the more delicate tints, while aniline dyes—the red especially—are indebted mainly to arsenious acid. To make the colour adhere to the surface, size or organic matter of some kind is introduced, whether it be used to stain paper or the fibres of which muslin is composed. This when dry cracks and peels off with the slightest friction. Besides this, some of the more potent forms of arsenic are very volatile, and become gaseous at a very low temperature, as evidenced by their odour and yellowish colour; and though the ordinary observer may not detect the vapours, they are carried and diffused by the motion of the air in the moist warm days of summer, and stealthily invade the skin and lungs in quantities that render them very potent for evil. From fourteen to seventeen grains have been found in each square foot of arsenical paper, while in certain papers printed with a peculiar pigment no less than fifty-nine per cent. of arsenious acid has been demonstrated.

Dr. Tidy tells us that "volatility and virulency usually go together." Now, the decomposition of the size or other vehicle for the colour produces a gas, known as arseniuretted hydrogen, which is quickly absorbed by the lungs and skin—even more quickly than the dust—and this gas is a most deadly poison.

Then again, green is by no means the only dangerous colour; others are fully as harmful. Blue, mauve, red, and brown have been found to contain great quantities of arsenic; even the delicate French greys yield it very considerably. In fact, paper-hangers complain of more discomfort in handling these grey papers than with most of the others. A farmer in Cambridgeshire lost three of his cattle owing to their having eaten some green paper which in the course of cleaning had been torn from the walls of the house in which he lived. Surely these are facts that will not bear trifling with.

Let us now glance at the evidence that has recently been obtained from the best and most trustworthy sources.

Some two years since the Medical Society of London appointed a committee to investigate this question. The committee issued a series of questions to the members of the medical profession, throughout England, and in reply received most satisfactory, though rather startling information; no less than one hundred cases of arsenical poisoning, of what may be called a domestic kind, being fully reported. Some of the most salient points of these I will quote in the words of the committee's report:—

Case i.—"For more than a year," writes a practitioner of eminence, "my own wife suffered repeated attacks (one of great severity) of enteritis.* The patient was in the habit of sitting the greater part of the day in a room papered with green paper. Without any reference to the symptoms, the paper was accidentally changed to another colour. It was noticed by me afterwards that the symptoms had disappeared. It then occurred to me that it might be due to the green pigment, and on testing a piece of the old paper, I found abundance of arsenic."

Case ii.—A physician and his wife suffered from conjunctivitis,† and from nausea after food. On the arrival of a relative, who soon was attacked in a similar manner, the cause was traced to the drawing-room paper, which contained arsenic.

Case iii.—A distinguished consulting surgeon lost two children from enteritis. The cause of the illness was a mystery until after their death, when the nursery-paper, the pattern of which was a fuchsia, leaves and blossom on a brown ground, was found to contain arsenic.

Case iv.—A medical man and wife suffered from headaches, nausea, and conjunctivitis, all of which were worse early in the morning. The symptoms abated when the bed-room paper was removed. It contained arsenic.

Case v.—A surgeon suffered severely for several days from extreme depression, diarrhœa, griping, and asthma at night; and his wife some days afterwards being affected with similar symptoms, the paint of the sitting-room was suspected by the physician in attendance. It was found to contain a large quantity of arsenic.

Case vi.—A consulting physician had a severe attack of enteritis, with hæmorrhage and great prostration. All the symptoms disappeared on the removal of the paper of his study. It contained a large amount of arsenic.

Case vii.—A physician, in reporting his own case, says he had "intense cephalalgia,‡ conjunctivitis, with intolerance of light, great depression, loss of appetite, with gastric irritation—worse when using the study, the wall-paper of which contained arsenic."

Case viii.—A physician says he suffered from griping, constipation, and headache for more than two years. He noticed that the symptoms were worse on entering the dining-room in the morning, after it had been closed during the night. "I soon recovered on the removal of the cause." The dining-room paper contained arsenic.

Case ix.—A consulting physician and his wife both suffered from restlessness, loss of sleep, malaise, and headache. The symptoms lasted a fortnight, but disappeared when the bed-room paper was removed. This was proved to contain arsenic.

Case x.—A surgeon says that his wife, child, and himself had irritable cough, accompanied by wakefulness, restlessness during sleep, and irritation of the eyelids. All the symptoms disappeared in a week or ten days after the removal of the bed-room paper, which contained arsenic.

Among the chief other cases reported, diarrhœa, nausea, and intestinal mischief occurred in thirty-five; severe depression in sixteen; conjunctivitis in nineteen; and cough, asthma, &c., in nine. Several instances of external irritation are mentioned, such as eczema§ from stockings and gloves, conjunctivitis from tulle dresses, eczema of the head from artificial flowers, &c.

It should be remarked that the foregoing statements have not emanated by any means exclusively from men having preconceived notions of the value of careful investigation in such circumstances. On the contrary, the conclusions arrived at by them have been forced upon their acceptance by stern necessity as the only solution of an enigma, and in many cases in direct opposition to their own *à priori* judgment and previous opinions. They are men, many of them, standing high in the profession, whose opinions should carry weight with their colleagues; and it

* Inflammation of the bowels. † Inflammation of the eye. ‡ Headache.
§ Inflammation of the skin.

follows that if only after much careful watching, and by a process of exhaustion or exclusion, they were able to determine the real sources of the evil, there must be a vast amount of information yet to be obtained when time and a better knowledge of this subtle poison and its workings shall have brought the profession to unite their efforts to sift and study the matter. As an illustration of the difficulty of tracing the symptoms to their actual source, no stronger fact could be adduced than that so large a percentage of the patients were living in the houses of the medical men themselves, and thus directly and constantly under their scrutiny. This seems to indicate that exceptional facilities are necessary to the discovery of the evil. Not only must the symptoms be watched and tested, but every article that suggests an explanation must be suspected. The occurrence and recurrence of the mischief under certain conditions will often lead to its detection. But as all these precautions involve much labour and assiduous attention, it is too much to expect them to be employed except by such as possess both the knowledge and the determination necessary to support them in their search, and make up their minds not to be baffled with a somewhat impalpable antagonist.

It will have been seen that plenty of other articles besides wall-papers are heavily charged with arsenical compounds. In the medical report from which I have quoted, thirty-six medical men attest to having traced cases of poisoning to arsenical paper, and five to paint, while very many more have detected the poison in stockings, wearing apparel, artificial flowers, bedsteads, and toys. It is gratifying to find that while some wall-paper manufacturers are using tons of arsenic per week in the production of colours, others are, with laudable motives, endeavouring to counteract the baneful practice by excluding from their factories every vestige of arsenic: in fact, buying no colours for use in printing without a guarantee that they are perfectly free from every taint of the dangerous metal.

Such firms would gladly co-operate with those members of the medical profession who, being conversant with the wide-spread evil that is being done, desire to see restriction placed upon the employment of arsenical pigments in every shape. In conclusion then, I would ask, Has not the time arrived when some such movement should be initiated with a view to making it compulsory that such articles should, at all events, be advertised as containing deleterious matter, in order that purchasers may be made aware of the danger they are incurring in their use? And if my humble efforts should be instrumental in moving some influential and public-spirited persons to direct the attention of the Legislature to the question, and so to bring about the much-needed reform, I shall not have written in vain. The thanks of all sanitary reformers are due to the noble energy and the painstaking work of Mr. Henry Carr, who has done much to call attention to this question. Those who are interested will do well to read his little but important book on "Our Domestic Poisons." To it and to Mr. Hogg's monograph I am indebted for much information, which I gratefully acknowledge.

It has occurred to me that, pending some definite legislation, it might be well to provide some easy test whereby those interested in the question could detect with certainty the presence of any arsenic in a suspected article. For it must be remembered that a mere inquiry of builders, vendors, &c., would inevitably be met by a comforting assurance, given in good faith, but utterly untrustworthy. To meet this difficulty, and to arrive at a just conclusion, a small but efficient test apparatus has been arranged, which, for an outlay of four shillings, can now be obtained from John J. Griffin & Sons, 22, Garrick Street, London, W.C. It consists of a wooden case, a wire-ring support, test-tube, lamp, pieces of sheet copper, and a piece of platinum wire.

INSTRUCTIONS FOR THE USE OF THE APPARATUS.

From the paper to be tested cut a piece four inches square, or if any particular colour be suspected, cut this colour in sufficient quantity to make up the above size. Let the portion to be tested be cut up into small pieces. Fix the wire support in the hole on the end of the case; place the test-tube in the ring; put the paper into the tube; add water till half full, then one tea-spoonful of hydrochloric acid (a glass measure or silver spoon should be used); light the lamp, moderate the flame, and place it underneath the test-tube. Take one of the coppers—if it is tarnished brighten it with a piece of glass-paper—pass the platinum wire through the small hole, and as soon as the fluid boils, insert the copper, noting the exact time, and lowering the flame of the lamp so as to maintain a gentle simmering only. By means of the platinum wire the copper can be drawn out and examined from time to time as the test proceeds.

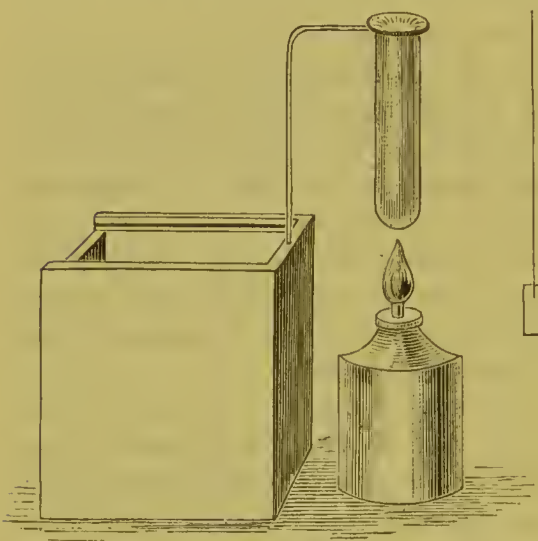


Fig. 180.—Test for Arsenic.

If there be much arsenic present the copper will be coated almost immediately with a black or dark steel colour; if less arsenic be present a longer time will be required, varying from half a minute to at most half an hour. If the copper be not coated all over in that time the paper may be accepted, the cases being rare in which this process does not detect the arsenic. A mere tarnish or slight discolouration of the copper must not be accepted as an indication of an arsenical paper The colour of copper must be obliterated entirely all over to constitute an arsenical coating. If the copper be coated the paper is, in all probability, arsenical, though the process carried thus far does not absolutely prove the presence of arsenic; the exceptions, however, where the copper is coated and arsenic not present, are rare. No paper which coats the copper should on any account be used, unless further tested by a professional chemist or medical man.

The purity of the copper and acid supplied with this apparatus by Messrs. Griffin may be relied upon, but if further supplies be obtained elsewhere they must be tested by boiling for half an hour as above described, but without any paper. If the copper then becomes coated at all, the materials are not pure, and must be rejected. Platinum wire must alone be used attached to the copper.

LIGHTING.

By Robert Brudenell Carter, F.R.C.S.

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CHAPTER XXXVI.

PHYSICAL NATURE AND PHYSIOLOGICAL EFFECTS OF LIGHT AND COLOUR.

Light consists of Ether Waves—Refraction—The Spectrum—Different Wave-Lengths produce Different Colours—The Colours of Bodies—Scattered Reflection—Selective Absorption—Fluorescence—Complementary Colours—Physiological Effects of Different Colours, and of Light generally—Testimony of Miss Nightingale.

The chief purpose of domestic lighting, whether by the admission and due regulation of solar light, or by the employment of one or more of the artificial substitutes for it, is to display the forms and colours of the objects contained within the house; and the proper fulfilment of this purpose is of primary importance to the comfort, the health, and the capacity for working of at least a large proportion of the inmates. Notwithstanding this, I fear that I incur no risk of contradiction when I say that the question is one which has not received a due amount of consideration from architects; who, in the great majority of instances, appear to plan their window openings almost entirely with reference to effect as seen from without, and certainly with very little regard either to the uses to which the interiors are to be applied, or to the proper incidence of light upon the eyes, or to the occupations which are to be carried on within the walls.

In order to understand the principles by which either natural or artificial illumination should be governed, it is necessary to possess some elementary knowledge of the nature of light itself, and of the physical changes or movements which are concerned in the production of visibility.

The researches of philosophers have led them to the conclusion that the world in which we live, and the vast spaces of the stellar heavens, are occupied and pervaded by an infinitely subtle fluid, called the luminiferous ether, which is thrown into a state of molecular vibration by force communicated to it by the sun of our system, and by other self-luminous bodies in the universe. These other self-luminous bodies, as far as their effect upon this planet is concerned, are of so little significance that they may be disregarded, and we may think only of the vibrations which originate in the sun. These throw the ether into wave movement, in a fashion of which the waves of the sea furnish an enormously magnified example; and it has been ascertained that each ether particle, like each water particle, rises and falls, or sways to and fro, in its own position, transmitting the movement which it has received, but not otherwise changing its place. The wave proceeds continuously; the ether remains where it was. The waves of ether, like the waves of the sea, present marked differences of length, of magnitude, and of rapidity of succession; and they are liable to be

broken up, altered, and changed from their original directions, by clashing against one another, or by meeting with physical obstacles of various kinds.

The general effect of wave movement is to spread in a circle from its point of origin, like the ripples which are produced when a stone is cast into still water; and hence it follows that the direction of such movement is at right angles to the wave crests, and may be exhibited by a series of lines drawn from the centre to all points of the circumference of the circle. In tracing the course of light, we may disregard the waves, and may think only of a force which is continually propagated in straight lines from its point of origin, and which is therefore diffused equally in all directions. Two equal surfaces, at equal distances from the same source of light, and separated from it by the same intervening matter, will receive precisely an equal amount of illumination.

In the assumed emptiness of stellar space, the vibrations of the ether are of almost inconceivable rapidity; but they become somewhat retarded in their passage through the atmosphere, and more retarded still in their passage through the many media of greater density which they encounter upon the earth's surface. The molecular constitution of these media, and the relations borne by the intermolecular ether to their molecules, are such as to produce great differences in the readiness with which vibrations are transmitted through their substance. In some the transmission is very considerable, and such are said to be transparent; while in others the vibrations are arrested, or repelled, or forced to assume new forms, and these are said to be opaque. There is no such thing as complete transparency or complete opacity, the light being in every case diminished as it enters a new medium, partly by being turned back from its surface, partly by being turned back from its deeper portions, and partly by being arrested or converted into other forms of force within its mass; while even a substance so opaque as gold, when beaten into thin leaf, permits the passage of a portion of the light which it receives.

The retardation of the speed of ether waves, when entering a more resisting substance, is not sufficient to be measurable by instruments when the new surface is at right angles to the line of advance. The whole ridge of the wave comes at once into contact with the new material, and enters into its substance simultaneously. But if the surface of the new material be presented to the wave in an oblique direction, so that one extremity of a wave reaches it before the other, the former extremity is retarded or checked before the other, and the wave as a whole is made to execute a movement which may be described as wheeling upon one of its extremities. The effect of this is that the wave is forced into an altered direction, so that the light no longer travels in a straight line from its origin, but is refracted, or bent out of its course. A similar effect is produced, but with a bend in an opposite direction, if the new medium affords less resistance than the original one.

If a circular or slit-like opening be made in the window shutter of a darkened room, upon the window of which the sun is shining, a rod or band of white light will pass through the opening, and will become apparent as a bright spot or line upon a screen suitably placed to receive it. If a prism of glass or other transparent medium, more resistant to wave movement than the atmosphere, is now placed in the path of the light, the latter, falling obliquely upon the surfaces of the prism, will be refracted, or bent out of its course, at both these surfaces, on entering

the more resistant medium, and again on leaving it, and will appear upon the screen in a new position. It will also appear in an entirely altered aspect; for, inasmuch as the whole beam, as already stated, is composed of a mixture of waves of different sizes and rates of vibration, these will be influenced in different degrees. Those of the greatest length will be less bent than others; and the effect of the prism is, therefore, to spread out the original spot or line of light into a band, the least refrangible or slowest-moving portions of which are less, and the most refrangible or quickest-moving portions of which are more, diverted from the track which was previously common to them all. The luminous band thus thrown upon the screen is called the prismatic spectrum.

The part of this spectrum which impresses the sense of sight, and is thus said to be visible, exhibits a succession of vertical bands of colour, which were described by Newton, who discovered them, as being red, orange, yellow, green, blue, indigo, and violet. The red is formed by the least refrangible rays, which possess the greatest wave-length; the violet by the most refrangible, which possess the smallest wave-length. Newton also found that, by employing a second prism to reverse the action of the first, he could re-combine the spectrum into a spot of white light; and he thus determined that solar light is a mixture, the whiteness of which is due to the proportions of its ingredients.

Newton's first impression was that the seven colours of the spectrum were all pure, or, as it was said, primary; but more careful subsequent examination has shown that, as white light is an admixture of them all, so four of the prismatic colours are the results of the admixture, by overlapping, of the adjacent bands. There was for a time much difficulty in determining which of the seven were really primary; but the claims of red, green, and violet are now well established, and orange, yellow, blue, and indigo are ascertained to be mixtures. It is also ascertained that beyond the visible red there are rays of still greater wave-length and less refrangibility, which make no impression upon the sense of sight, but are sources of heat; and that beyond the violet there are other invisible rays of still greater refrangibility and still smaller wave-length, which are potent sources of chemical activity. Sir William Grove long since pointed out that all the forms of physical force known to us—as motion, light, heat, electricity, magnetism, and chemical affinity—are transmutable into one another; and it may be assumed that they are all alike the effects of molecular vibration originated in the sun, and transmitted to us through the medium of the ether. The long slow waves beyond the visible red of the spectrum, which produce no effect upon our organs of vision, because these are not so constructed as to vibrate in unison with them, are, no doubt, more potent sources of heat than the waves of greater rapidity; and the small very rapid waves beyond the visible violet, which are unseen for the same reason as those at the other end of the spectrum, are, no doubt, more potent in shaking asunder the molecules which enter into the formation of chemical compounds than waves of less rapidity; but, notwithstanding this, both heat and chemical action are discoverable effects of every portion of the solar beam.

Our present business, however, is neither with the heat-producing nor with the chemical effects of solar rays, but only with the coloured or visible portion of the spectrum. With regard to this portion, the fact which chiefly concerns us is that light waves of different lengths and rapidities produce different sensations, to which

we give the name of colours; and that these sensations may be almost infinitely varied by varying the proportions in which light of the three primary wave-lengths is intermingled, and in which this coloured light is mixed with white light from other sources. It is important to remember that what we call colour has no real existence as such, but is merely a name used to denote the impressions made upon the eye by ether vibrations of different magnitudes.

The effect of a mixture of different wave-lengths in modifying the general movement may be best apprehended by studying the similar effects which, upon a large scale, are constantly to be witnessed in water. The waves produced by a stone, overtaking and mingling with those produced by a ripple on the surface, may serve to show that the result of the two movements is something very different from either of them when taken singly; and it is the result of similar comminglings of the waves of light which is presented to the eyes in looking at surrounding objects. It is at first somewhat difficult to conceive that the mere blending of different quantities or proportions of the sensations which we call red, green, violet, and white, can produce the whole of the diversified tints with which we are familiar; but this difficulty vanishes when we remember that each of these names is a general expression for vibrations which are so minute that many thousands of them are required to cover an inch of length, and which are therefore so numerous that, regarding each vibration as a constituent unit of colour, they admit of an infinite number of combinations. In round numbers, an inch of length will contain about thirty-five thousand waves of red, about fifty thousand of green, and about sixty-two thousand of violet; and the rapidity with which these waves succeed each other, although it admits of being written down in figures, is such that these figures can scarcely be said to convey any real conception to the mind. In its journey from the sun to the earth, light travels at the rate of 186,000 miles in a second. In this distance there are 11,784,960,000 inches; and even in red light there are, at the lowest computation, 33,866 waves in an inch. It follows that, in looking at red light, the eye receives the impact of no less than 399,109,455,360,000 waves in every second of time. In looking at light of any other colour, the number of waves per second will be still larger, and the capacity for variation is evidently one to which it would be impossible to place a limit. We may form some notion of this capacity if we remember that, according to Mr. Procter, the fifteen pieces of the "Boss" puzzle will admit of more than twenty-eight millions of possible positions.

Even in the case of bodies of the greatest known transparency, the light which they receive does not all enter into their substance, but is in part reflected or turned back. When the reflected surface is smooth, the light falling upon it is reflected in one definite direction, which is expressed by saying that the angle of reflection is equal to the angle of incidence, and that the incident and the reflected light are in the same plane. The reflection is like that of a billiard-ball from the side cushion against which it strikes. When the surface is rough, it really consists of numerous surfaces in close juxtaposition, with their faces turned in various directions; and hence, although the law of reflection remains the same, the light is sent in a like number of directions, and is scattered as regards the observer placed at any single point. This may be conveniently illustrated by Fig. 181, Nos. 1, 2, 3. No. 1 represents the mode of reflection from a smooth and polished surface, like glass, which sends all the rays incident from the same source in the same direction.

No. 2 represents a slightly roughened surface, like paper, in which some of the points of reflection turn the light one way, some another, and the reflected beam is no longer formed of parallel rays. They are scattered about, and the image they form is confused and indistinct. No. 3 represents a rough surface, like cloth, by which the incident rays are scattered in every direction, so that no image is produced. The drawings may be explained by the following experiment :—

"Place a lighted lamp upon a table, and lay a mirror before it, and you can

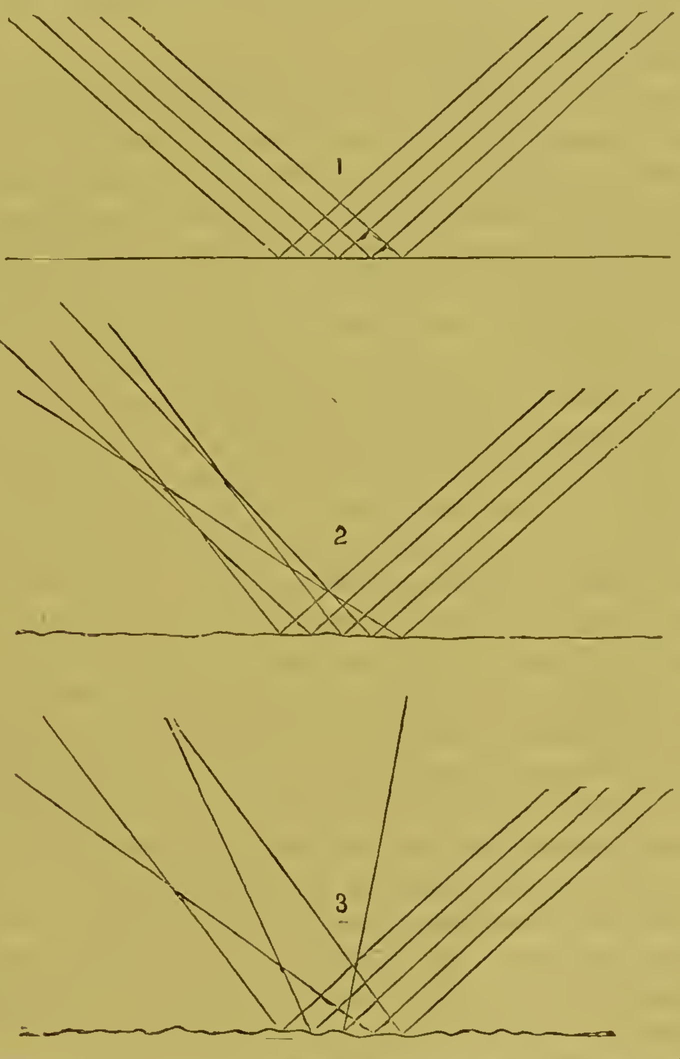


Fig. 181.—Reflection from (1) Polished Glass, (2) Paper, (3) Cloth.

see a clear and distinct reflection of the lamp and the flame pictured in the glass. Put a sheet of white paper before the lamp, and you can see only a confused spot of reflected light on the brightly lighted paper. Lay a freshly ironed napkin or handkerchief before the lamp, and even the indistinct spot of light has disappeared, and the white cloth reflects light equally from every part."*

Of the whole amount of solar light which falls upon any substance at a given time, a certain portion is reflected, or turned back, from the very surface, and this

* Taken by permission from "Light: a Series of Simple, Entertaining, and Inexpensive Experiments." By A. M. Mayer and C. Barnard. Macmillan and Co.

portion, which, as we have just seen, varies in amount with the smoothness of the surface as well as with the nature of the reflecting substance, is always white, or complete solar light. Another portion may pass through the substance, and emerge on the other side, altered in direction, as we have seen, if its angle of incidence is not a right angle. A third portion may be altogether quenched or absorbed within the mass; the physical change which then occurs being that the speed of the waves is retarded until they can no longer display themselves as light. They become converted into heat waves, and, when finally arrested within the substance, they produce elevation of its temperature.

Excepting the surface, which, as stated above, always reflects white light in its integrity, or the same admixture of wave-lengths which it receives, all other portions of most substances have some selective affinity for waves of particular lengths, and arrest or turn back others. When we say that a piece of glass is red, we mean that it gives free passage to the red element in solar light, but that it stops the remaining elements, either turning them back or arresting and converting them into heat rays. Hence, when we look through it we receive no rays but those of the greatest wave-length, which affect the consciousness in the manner which we describe by the word "red." When we say that a piece of woven stuff is green, we mean that, besides the white light which falls upon it and is reflected from its surface, a certain further amount of white light penetrates somewhat into its substance, and is reflected back from its deeper layers, leaving in them, on its backward way, the red and violet which it originally contained. The resulting colour is compounded of these two distinct sources of light, and the appearance which it presents differs according to the greater or lesser amount of white light which is reflected from the absolute surface to mingle with the green coming from the deeper portions of the fabric. Hence, mainly, the difference in colour, even when dyed by the same substance, between a surface of highly reflecting character, such as satin, and one which reflects sparingly, as in the case of woollen fabrics generally.

The varieties of colour which we see around us depend, therefore, in almost every case, upon some subtraction from the white light furnished by the sun or by some secondary source, and this subtraction is usually the result of selective absorption on the part of the substance on which light falls, and which is said to be coloured. Instead of transmitting white light if transparent, or instead of reflecting it if opaque, it retains within its structure waves of certain periods of vibration, and thus transmits or reflects an altered or coloured admixture. This, as we shall see hereafter, has important practical bearings upon the use of tinted window glass, as well as upon the selection of coloured shades for lamps.

The apparent colours of objects are greatly determined by the colours of the illumination which they receive. If, in an otherwise darkened room, we throw the solar spectrum upon a screen, and then hold coloured objects, such as pieces of ribbon, first in one band of colour and then in another, the ribbons will appear dark or black in certain portions of the spectrum, and illuminated in others. A red ribbon held in the red band reflects nearly all the light which falls upon it, and appears of increased vividness; moved into the green, it appears absolutely black, because ~~green~~ ribbon absorbs and retains all red light, and in this case receives nothing which it is able to return. A piece of green ribbon, again, will shine brightly in the green band, and will appear black in the red one. But in nearly

all cases in which objects are lighted up by one prismatic colour in nature, they are at the same time lighted by white light derived from other sources, so that the ultimate effect is derived from a combination of the two modes of illumination. A familiar example of this is often afforded on a summer evening, soon after sunset, when there is a cloudless blue sky overhead, and rosy-tinted clouds near the horizon. The blue of the sky depends upon the presence in the atmosphere of innumerable particles of almost inconceivable minuteness, against which the light waves ripple and break, and which reflect the blue somewhat in excess; while the red tints of sunset are due to the interception by the atmosphere of considerable portions of the green rays. In the supposed conditions, such flowers as the red geranium and the blue lobelia, lighted up by the abundant red and violet of the horizontal light, display their colours with unusual brilliancy; while the bright geranium leaves or the blades of grass, receiving green enough in the white light which still falls upon them from the zenith, are not only of full colour, but seem even more bright than usual, from the contrast which they afford to the blossoms.

An occasional source of colour is furnished by the phenomenon called fluorescence; and although this is not exhibited on a sufficient scale to be of much practical importance with reference to the present subject, it must not be left wholly without notice. We have seen that beyond the visible red of the spectrum there is a band of waves which are too long to excite sensations of light in the human eye, to which they are invisible, although they may be rendered manifest as sources of heat; and that, in like manner, beyond the violet, there are other invisible rays, the vibrations of which are too rapid to excite the human eye, and which are active as causes of chemical change. When these rays, which are called the "ultra-violet," are suffered to fall upon certain substances, of which uranium glass, solutions of quinine, and infusion of horse-chestnut bark are the most familiar, they are so much retarded as to produce in these substances vibrations which, when communicated to the surrounding ether, become visible, and the objects, during and after exposure to the darkness of the ultra-violet rays, shine as if with independent luminosity. With some fluorescent substances, the effect thus produced is of considerable duration, and it has lately been turned to account in the arts as a source of the so-called luminous paint, and also as a means of rendering such objects as watch and clock dials, match-boxes, the number-plates on the doors of houses, and other things, sufficiently luminous to be seen at night after they have been exposed to sunlight during the day. The element in sunlight by which the effect is produced is not anything which is itself visible, but only the ultra-violet ray; and if this could be intercepted while the rest of the solar light was suffered to fall upon the object, no luminosity would be produced. Artificial sources of light which are rich in blue may be used instead of sunlight, and one of the best known of these is furnished by the combustion of magnesium wire, which also, from the abundance of the ultra-violet which it yields, has been employed as a means of producing photographs in places from which sunlight is excluded.

Such being, in the most meagre outline, the nature of light and of colour, we have next to consider in what way these are subservient to the exercise of vision. The eye is an instrument resembling the camera of the photographer, and its especial function is to arrange the light reflected from objects in an inverted picture upon its retina, or sensitive screen of nerve-tissue, by which the impression made by this

inverted image is received, and from which it is propagated to the brain, to become a subject of consciousness. The perceptive layer of the retina is an exceedingly fine mosaic of nervous terminations of two kinds, called, from their respective shapes, rods and cones; and it is believed that the size of these elements has an important bearing upon the limitations of magnitude within which ether vibrations produce the impression of light. It would seem as if, for this effect to be produced, the waves must neither exceed nor fall short of a certain proportion to the rods and cones; and it is possible that an unusual size of the nerve elements, rendering them insensitive to some of the vibrations which are perceptible to the majority of mankind, may be at the root of the curious condition known as colour-blindness, the subjects of which are unable to perceive at least one of the three primaries of the spectrum, and thus see all colours modified as they would be by its absence. Recent researches point to the conclusion that the act of vision consists essentially of a chemical change, consisting of the destruction, by the influence of the light waves, of a material called vision-purple, which appears to be constantly renewed in the living retina; but this has no present bearing upon the questions which we have now to consider. The essentials of good lighting are that the eye should receive light enough to furnish the materials for a vivid retinal image, and not enough to be dazzling or distressing; and that the illumination should be of such a kind as to reproduce in the retinal image the natural colours of objects. For this purpose, it must either contain all the primaries in the due proportion to constitute white light, or it must at least contain them in the proportions in which they are reflected from the object looked at. In a room supplied only with red light, all green objects would appear black, and *vice versâ.*

It has long been known, as a matter of observation, that the combinations or contrasts of certain colours are pleasing to the eye, while others are harsh and inharmonious; and, after the discovery by Newton of the compound character of light, it was soon found that the harmonious and pleasing combinations were those in which the colours were "complementary," that is, in which they would make up white light if blended together. Although early known with regard to the apposition of two contrasted colours, the same principle has not been so widely recognised with regard to multiple combinations; and it was reserved for Professor Barff to call attention to the fact that the secret of smooth and pleasant colouring in a picture, a stained window, or generally in the free distribution of colour for decorative purposes, is to be found in the use of combinations which, taken collectively, make up white light. The study of the complementary colours was for a long time obscured by the absence of discrimination between light and pigments: forms of colour which may be alike to the eye, and which nevertheless produce by their admixture totally different effects. For example, blue light is complementary to yellow light; and the two, when mixed or superimposed in the proper proportions, produce white by their union. The mixture of blue and yellow pigments, on the contrary, produces green, for the simple reason that this is the only colour reflected by them both. The difference has been well explained by Mr. Ogden Rood, who points out that "by mingling two pigments we obtain the resultant effect of two acts of absorption due to the two pigments; white light is twice subjected to the process of subtraction, and what remains over is the coloured light which finally emerges from the painted surface. On the other hand, the process of mixing

coloured light is essentially one of addition; and this being so, we find it quite natural that the results given by these two methods should never be identical, and often should differ widely." *

The complementary colours form practically an almost infinite series, the complementary colour of any given mixture being all that is omitted from it when compared with white light. As illustrations of a few pairs, Ogden Rood gives the following table :—

Red	Green-Blue.
Orange	Cyan-Blue.
Yellow	Ultramarine-Blue.
Greenish-Yellow	Violet.
Green	Purple.

These pairs, of course, might be indefinitely increased in number, but they are sufficient to give an idea of the principle at issue, and of the manner in which it may be applied in order to produce harmony of colour in lighting and decorating apartments. If we admit into any room too much of one of the ingredients of white light, without balancing it by careful admixture elsewhere, the result will not only be disagreeable, but will also disguise the outlines of all contained objects which are of such a nature that they tend to absorb, rather than to reflect, the colour which has thus been rendered predominant.

The influence of differently coloured light upon the eye, either as regards the acuteness or the duration of vision, is a subject which has scarcely at all engaged the attention of experimental philosophers. Dr. Ludwig Boehm, of Berlin, stands almost alone in having even referred to it; and his statements are so much under the influence of a strong belief in the value of blue light as an actual agent in the treatment of certain forms of eye disease, that they can only be accepted with a certain amount of reserve. He asserts, however, that industrial occupations often furnish undesigned but striking proof of the different action of different single colours upon human eyes; and he quotes especially his observations at an embroidering establishment in Berlin, at which fifty workwomen were engaged in embroidering upon and with silken materials of all colours, and often upon satins of highly reflecting surface, on which the most important patterns were previously traced out in black lines. The unvaried experience of many years, even with the youngest and strongest eyes, went to show that yellow, and still more apple-green, were of all colours the most inimical to the continuance of visual effort. Even in the daylight, embroidery upon fine silks of these colours could not be accomplished except by the aid of frequent interruptions. The traced patterns would after a few minutes' application become invisible, and the embroideress would see nothing but the coloured surface. In artificial light no embroidery upon apple-green can be attempted. On the other hand, the colour most pleasant to work upon was by all declared to be blue; although prolonged work upon a blue surface was said to produce headache. Dr. Boehm, who will hear nothing against his favourite colour, explains this headache by supposing that the soothing influence of the blue upon the retina permitted work to be continued so closely and uninterruptedly, that the brain and the attention became wearied before the eyes themselves experienced any desire for rest.

* "Modern Chromatics," p. 143.

Dr. Boehm's notions about blue light have at least this much of plausibility: that he attributes many of the beneficial properties which he claims for it to its high refrangibility. It is, as we have seen already, the most refrangible portion of the solar light: or, in other words, it will be brought to a focus at some given distance by a weaker lens than the other portions. Hence, no doubt, it calls upon the lenses of the eyes for a somewhat smaller degree of adjustment effort than would be demanded of them even by white light, and therefore, *à fortiori*, far less than would be demanded by any other colour; but it remains to be proved whether the difference thus indicated would be sufficient in degree to produce any noteworthy effects; and, as we shall see hereafter, it would be opposed by the fact that blue light, as contrasted with white light, means practically a much diminished illumination, and a corresponding approximation of the object of vision. The adjustment effort of the eye, and the muscular work incidental to vision, are increased in a marked manner by such approximation; and hence, for any occupation requiring near and accurate seeing, it is more than doubtful whether Dr. Boehm's observations are trustworthy. It may, no doubt, be conceded that light in which the blue element is in excess, although not to the exclusion of all others, is by most persons felt to be soothing and grateful.

In opposition to Dr. Boehm, Dr. Bouchardat, of Paris, has lately delivered a lecture in which he condemns blue light, or even light containing the normal proportion of blue, for visual purposes, and recommends a preponderance of dull yellow, taking the flame of a tallow candle as his ideal of what is most to be desired. He appears to have no other ground for this opinion than a fear lest the fluorescence produced by blue rays in the humours of the eyes should exert an injurious influence upon them; but for this fear, as far as I am aware, there is not any shadow of foundation, either in scientific principles or in practical experience.

The analogies between the animal and vegetable kingdoms are often extremely close; and the action of coloured light on plants was investigated, many years ago, by Dr. Draper, whose experiments and conclusions have remained unchallenged. He found that the fixation of carbon from the atmosphere, on which the growth of plants depends, was carried on more actively under yellow light than under any other, and that the seven colours of the Newtonian spectrum promoted the process in the following order:—(1) yellow, (2) green, (3) orange, (4) red, (5) blue, (6) indigo, (7) violet. This is very remarkable, as seeming to show that the change in question, occurring most freely in a region of the spectrum equi-distant from the most powerful heat rays and the most powerful chemical rays, is not entirely dependent either upon chemical activity or upon temperature, but partly also upon some other influence, the precise nature of which requires further investigation. The interesting experiments of Dr. Siemens, in growing plants under the electric beam, might probably be so extended as to allow the relative powers of the different parts of the spectrum upon vegetation to be tested in a more complete way than has ever hitherto been possible.

It is perhaps worth while briefly to notice, if only for the purpose of pointing out its character, an absurd book about Light which has recently been published by an American charlatan, under a title which is well calculated to deceive purchasers into the belief that they are buying a scientific treatise. The object of this book is to advertise the pretensions of its author to cure diseases of all kinds

by what he calls baths of coloured light: that is to say, by persuading his dupes to sit unclothed in sunshine which streams through a window filled with panes of coloured glass, which are so moved from time to time as to allow red, green, or violet rays to fall upon the part supposed to be affected. These windows, and other like appliances for the use of coloured light, are sold by the writer; who, among other drolleries, professes to "medicate" water by keeping it for a time in coloured glass bottles of various forms. It will assist in estimating this nonsense at its true value if we remember that the pane of coloured glass does not add anything to the solar light, but only withdraws something; so that, unless the colour which is withdrawn would be actively injurious, all the good effects would be equally obtained from the sunlight shining through a common window. On the other hand, if the light which is withdrawn were actively injurious, the patient would surely require a protection from it more complete, and for longer periods, than this method of so-called treatment could afford. It is worth remembering that baths of sunlight, under the name of *Solaria*, were much in vogue among the Romans in ancient times, and were, no doubt, in some instances beneficial.

For, while the preceding paragraphs express the state of our knowledge—or, more properly, of our want of knowledge—concerning the special effects upon the animal body of different kinds of light, there is no ambiguity whatever in our knowledge of the importance of light generally as a stimulant of—or perhaps, more properly, as a condition of—what is comprehensively termed vital action. The potatoes which germinate in a dark cellar, and push out straggling, white, and sickly shoots towards any chink by which sunbeams penetrate the darkness, the artificially bleached celery and sea-kale of the gardener, the children who grow up in the shaded lanes and dark alleys of great cities, the workpeople who labour in cellars or mines: all alike proclaim the great truth that life without sunlight is only half living. Want of sunlight to the human race means stunted bodies, imperfectly formed blood, feeble limbs, dull senses, and torpid minds. Essential to the well-being of those who are reputed to be healthy, it is no less essential to the recovery of the sick. There are well-authenticated instances of hospitals having a light and a dark side, in which the percentages of recovery have been distinctly greater on the former; and a like influence upon the health of inmates has been repeatedly observed in schools, barracks, asylums, and other public buildings. One of the chief difficulties to be contended against by Arctic explorers accustomed to more genial climates—a difficulty even greater than that arising from the cold—is the confinement to the ship during six months of darkness, and the sacrifice of health which the deprivation of light is found to entail. On the subject of the importance of light to the sick, Miss Nightingale has some remarkable observations, the truth and importance of which will furnish a sufficient apology for quoting them. She says:—

"Second only to fresh air, however, I should be inclined to rank light in importance for the sick. Direct sunlight, not only daylight, is necessary for speedy recovery; except, perhaps, in certain ophthalmic and a small number of other cases. Instances could be given, almost endless, where, in dark wards or in wards with a northern aspect, even when thoroughly warmed, or in wards with borrowed light, even when thoroughly ventilated, the sick could not by any means be made speedily to recover."

"Who has not observed the purifying effect of light, and especially of direct

sunlight, upon the air of a room? Here is an observation within everybody's experience. Go into a room where the shutters are always shut (in a sick-room or a bed-room there should never be shutters shut), and though the room be uninhabited, though the air has never been polluted by the breathing of human beings, you will observe a close musty smell of corrupt air—of air, *i.e.*, unpurified by the effect of the sun's rays. The mustiness of dark rooms and corners, indeed, is proverbial. The cheerfulness of a room, the usefulness of light in treating disease, is all-important."

"Heavy, thick, dark window or bed curtains should, however, scarcely ever be used for any kind of sick in this country. A light white curtain at the head of the bed is, in general, all that is necessary, and a green blind to the window, to be drawn down only when necessary."

"'Where there is sun there is thought.' All physiology goes to confirm this. Where is the shady side of deep valleys, there is Cretinism. Where are cellars and the unsunned sides of narrow streets, there is the degeneracy and weakness of the human race—mind and body equally degenerating. Put the pale withering plant and human being into the sun, and, if not too far gone, each will recover health and spirit."

"It is a curious thing to observe how almost all patients lie with their faces turned towards the light, exactly as plants always make their way towards the light. A patient will even complain that it gives him pain lying on that side. 'Then, why do you lie on that side?' He does not know, but we do. It is because it is the side towards the window. A fashionable physician has lately published in a Government report that he always turns his patients' faces from the light. Yes; but Nature is stronger than fashionable physicians, and depend upon it she turns the faces back, and *towards* such light as she can get. Walk through the wards of a hospital, remember the bedsides of private patients you have seen, and count how many sick you ever saw lying with their faces towards the wall."*

* "Notes on Nursing."

CHAPTER XXXVII.

NATURAL DAYLIGHT, AND WINDOWS.

Sir David Brewster on Light and Health—Light and Dirt—Various Architects upon the Size of Windows—Empirical Rules—Position of the Window—School-rooms—Expedients for increasing Deficient Light.

THE late Sir David Brewster, in his address delivered to the Royal Society of Edinburgh, at the opening of the session of 1866-67, after passing in review some of the known hygienic effects of sunlight, and some of the consequences of its exclusion, continued in the following words :—

"If the light of day contributes to the development of the human form, and lends its aid to art and nature in the cure of disease, it becomes a personal and national duty to construct our dwelling-houses, schools, workshops, factories, churches, villages, towns, and cities upon such principles and in such styles of architecture as will allow the life-giving element to have the fullest and the freest entrance, and to chase from every crypt, cell, and corner the elements of uncleanness and corruption which have a vested interest in darkness.

"Although I have not visited the prisons and lazarettos of foreign countries, to describe the dungeons and caverns in which the victims of despotism and crime are perishing without light and air, yet we have seen enough in our own country—in private houses, in the most magnificent of our castles, and in the most gorgeous of our palaces—to establish the fact that there is hardly a house in town or country without dark apartments which it is in the power of science to illuminate. In most of the principal cities of Europe, and in many of the finest towns of Italy, where external nature wears her brightest attire, there are streets and lanes in which the houses on one side are so near to those on the other that hundreds of thousands of human beings are neither supplied with light or air, and carry on their trades in almost total darkness. Providence—more beneficent than man—has provided the means of lighting up to a certain extent the workman's home by the expanding power of the pupil of his eye, and by an increasing sensibility of his retina; but the exercise of such powers is painful, and every attempt to see when seeing is an effort, or to read and work with a straining eye and an erring hand, is injurious to the organ of vision, and sooner or later must impair its powers. Thus deprived of the light of day, thousands are compelled to carry on their trades principally by artificial light—by the consumption of tallow, oil, or gas—thus inhaling from morning till midnight the offensive odours and polluted effluvia which are more or less the products of artificial illumination.

"It is in vain to expect that such evils, shortening and rendering miserable the life of man, can be removed by legislation or arbitrary power. In various great cities attempts are making to replace their densely congregated streets and dwellings by structures at once ornamental and salutary; and Europe is now admiring that great renovation in a neighbouring metropolis by which hundreds of streets and thousands of dwellings, once the seat of poverty and crime, are replaced by architec-

tural combinations the most beautiful, and by hotels and palaces which vie with the finest edifices of Greek or of Roman art."

Sir David Brewster, in the foregoing passage, does not himself attempt to grapple with the question of the disposal of the poverty and crime which were rooted out from their sometime haunts; and this problem, however important, is foreign to the purpose of these pages. The citations which I have made will suffice to establish, on the authority of an eminent physical philosopher, and on that of a nurse of consummate skill—if, indeed, such establishing can be considered necessary—that without sunlight there can be no real welfare, and that, in planning houses, the provision of an abundance of window space, and the placing of the windows in positions to receive the full rays of the sun, form most important parts of the duties of the architect. Miss Nightingale elsewhere lays stress upon what is indeed a truism, but nevertheless, one which should constantly be repeated and enforced—namely, that an excess of sunlight can be excluded when there is need, but that a deficiency of sunlight, depending upon errors of construction, cannot be supplied while the construction remains. "Window-blinds," she says, "can always moderate the light of a light ward, but the gloom of a dark ward is irremediable. The escape of heat from large windows may be diminished by plate or double glass; for, while we can generate warmth, we cannot generate daylight, or the purifying and curative effects of the sun's rays."

To the foregoing considerations I would add yet one more—and, as regards the wholesomeness of dwellings, by no means the least to be considered—in the fact that, given ordinary housewifery, darkness may be used as a synonym for dirt. If a room is generally dark, that room will also be dirty. If a room is moderately well lighted on the whole, but has corners or recesses into which the light does not freely penetrate, those corners or recesses will be dirty corners or recesses. Fluff and dust will collect in them; the broom of the average housemaid will describe a curve which fails to penetrate into their depths; and they become receptacles for decaying organic matter of various kinds, poisoning the air of the occupants, mingling with their food, sometimes actively hurtful, never wholly innocuous. Physicians are coming to the knowledge, by slow degrees, that household dirt is among the most frequent and most potent of the causes of common illnesses; and a mistress must be almost superhuman if she can wage successful war against household dirt which is fostered and sheltered by darkness. This influence, which is very considerable in the homes even of the wealthy, is far greater in those of the poor. In cottages with good window space, and with a fair allowance of sunshine, the filth which may be found in those less favourably constructed, but inhabited by persons of the same class, is practically unknown. No doubt, there is much to be wished for even in the former, but the state of the two will usually admit of no comparison.

The necessity which is thus imposed upon us of admitting light freely into our rooms is tempered by the other necessity of remembering that human eyes may be injured by exposure to an illumination which is either too direct or too brilliant. The variations in the size of the pupillary opening, which, in a general way, regulate the amount of light admitted into the interior of the eye, are not sufficiently prompt, on passage from a dark into a brilliantly-lighted apartment, to prevent the production of some dazzling and distress. When the light is excessive, even the greatest contraction of the pupil is not enough to afford entire protection; and there have been many

instances in which sudden exposure of the eyes to bright light has proved permanently injurious to them. Looking at the sun through imperfectly smoked glass, looking at a bright object on the stage of a microscope at the moment when a cloud has passed away, and has allowed the full sunshine to fall upon it and to be reflected upwards, travelling over snow in sunshine without dark glasses or other suitable protectors, are illustrations of some of the ways in which such effects have been produced; and they teach us that although sunlight should be freely admitted into rooms, it should not fall too directly either upon the eyes themselves or upon the objects of vision. The desired result is to be attained partly by the size and the position of the window, partly by its aspect, partly by the material of which it is made, and partly by the blinds and curtains with which it is furnished.

As regards the cardinal point of size, I cannot discover the existence of any universally accepted canon of proportion amongst architects, by which a certain superficial area of window surface is allotted as being indispensable for a certain cubic space of room. It seems clear that there must be a minimum proportion within which good lighting cannot be expected; and it is also clear that the window surface which would be sufficient with an uninterrupted outlook, would not be sufficient in a narrow street, or in the face of any obstacle interfering with the approach of light. The amount of window space now given in a building is probably regarded chiefly from the stand-point of architectural style; and this, if so, furnishes a weighty argument against the use, in northern countries, of styles which may be well adapted for the more brilliant sunshine of the south. In such a building as the new Law Courts, for example, in which business of the first importance will constantly be in progress, and in which, from every consideration of health and of convenience, the smallest possible use should be made of artificial lighting, the choice of a style should have been materially influenced by the consideration that one, more harmoniously than another, would carry sufficient window openings to allow the comparatively faint light of our grey skies to penetrate into the interior in adequate quantity.

It must not be supposed, from the absence of any rule upon the subject, that it has entirely escaped the attention of architects; but the following passages, extracted from Gwilt's Encyclopædia, will express almost the whole of what has been laid down by authorities with regard to it:—

"Vitruvius, Palladio, Scamozzi, and Philibert de L'Orme, besides many other masters, have given different proportions to windows as connected with the apartments to be lighted. That these should be different is indicated by the different places in which those masters have written. Nothing, indeed, seems so much to disallow general laws as the proportions of windows to an apartment, according to the climate, the temperature, the length of the days, the general clearness of the sky, the wants and customs of commerce and of life generally. In hot climates the windows are always few in number and small in dimensions. As we approach those regions where the sun has less power and the winter is longer, we observe always an increase in their size and number, so as to enable the inhabitants to take as much advantage as possible of the sun's light and rays. It seems, therefore, almost impossible to give general rules on this subject. We shall on this account endeavour, in the rules that this section contains, to confine ourselves to the sizes which seem

suitable in this climate, as respects the proportion of light necessary for the comfort of the apartment.

"It is a matter of experience that the greatest quantity of light is obtained for an apartment when lighted by an horizontal aperture in the ceiling. Of this a very extraordinary verification is to be found in the Pantheon at Rome. This edifice, whose clear internal diameter is 142 feet 6 inches, not including the recesses behind the columns, is nearly 74 feet high to the springing of the dome, which is semi-circular. The total clear number of cubic feet in it may therefore be taken in round numbers at 1,934,460. Those who have visited it well know that it is most sufficiently and pleasantly lighted, and this is effected by an aperture (the *eye*, as it is technically called) in the crown of the dome, which aperture is only 27 feet in diameter. Now, the area of a circle 27 feet in diameter being rather more than 572 feet, it follows that each superficial foot of the area lights the astonishing quantity of nearly 3,380 cubic feet. Independent of all considerations of climate, this shows the amazing superiority of a light falling vertically, where it can be introduced. But in a majority of cases the apertures for light are introduced in vertical walls; and the consequence is that a far greater area of them for the admission of light becomes necessary. In considering the question, it must be premised that a large open space is supposed before the windows, and not the obstructed light which it is the lot of the inhabitants of closely-built streets to enjoy. Again, it is to be recollected that in the proportioning of windows it is the apartments on the principal floor that are to be considered, because their width in all the storeys must be guided by them, the only variety admissible being in the height. In this country, where the gloom and even darkness of wet, cloudy, and foggy seasons so much prevail, it is better to err on the side of too much rather than too little light, and when it is superabundant to exclude it by means of shutters and blinds. We are not very friendly to the splaying of windows, because of the irregularity of the lines which follows the practice; but, it must be admitted, it often becomes necessary when the walls are thick, and in such cases a considerable splay on the inside increases the light in effect by a great diminution of shade. It is well, if possible, to have an odd number of windows in an apartment, nothing wherein contributes more to gloom than a pier in the centre.

"We do not think it necessary to advert to the rule of Palladio for the dimensions of windows given in the first book of his work, because, were it true for the climate of Northern Italy, it would not be so for that of Great Britain. Neither are we at all satisfied with that which in his practice Sir William Chambers says he adopted, and which is as follows, in his own words:—'I have generally added the depth and height'—we suppose width—'of the rooms on the principal floor together, and taken one-eighth part thereof for the width of the window—a rule to which there are few objections. Admitting somewhat more light than Palladio's, it is, I apprehend, fitter for our climate than his rule would be.' This rule is empirical, as, indeed, is that on which we place most dependence, and to which we shall presently introduce the reader, being ourselves inclined to the belief that in the lighting a room there is a direct relation between the area of the aperture admitting the light and the quantity of cube space in the room. Indeed, the law which we are about to give is one founded on the cubic contents of the apartment, and if the results bore a regular ratio to that quantity, the discussion would be at

an end. for we should then only have to ascertain the cubic contents, and knowing how much an area of light one foot square would illuminate, the division of one by the other would supply the superficies of windows to be provided. Our own notion on this subject is, that one foot superficial of light in a vertical wall, supposing the building free from obstruction by high objects in the neighbourhood, will in a square room be sufficient for 100 cube feet, if placed centrally in such room. It will, however, immediately occur to the reader that this rule cannot in many cases satisfy the requirements of an apartment as respects the quantity of light necessary for its proper illumination. The subject is beset with numerous difficulties, which to overcome requires the greatest skill. In the case of an apartment long as compared with its width, it is well known to every practical architect that windows of the same collective area at either of the narrow ends of such apartment will light it much more effectively than if the same area of light were admitted on either of the long sides, and most especially so if it should happen that on such long side there were a pier instead of a window in the centre of such side. In illustration of what we mean, let us refer the reader to the ball-room at Windsor Castle, an apartment 90 feet long, 34 feet wide, and 33 feet high. This room is lighted from the northern narrower side by a window nearly occupying the width, and is supplied by an abundance of light. But had the same quantity of light been admitted from either of the long sides of the room, so many masses of shadow would have been introduced through the interposition of piers that its effect would have differed most widely from the cheerful and airy aspect it now presents. We have taken this as an example that more presently occurs to us, but the reader, from his observation, will have no difficulty in supplying instances in corroboration of our impressions on this subject.

"But we shall now proceed to give, in the author's own words, the rule of which we have spoken. That author is Robert Morris, and the work quoted is 'Lectures on Architecture, consisting of Rules founded on Harmonick and Arithmetical Proportions in Building.' 'There are rules, likewise, for proportioning of light according to the magnitude of the room, by which any room may be illuminated more or less, according to the uses of them, and at the same time preserve an external regularity; which, as it is on an uncommon basis, I shall explain to you as well as I conveniently can. Let the magnitude of any room be given, and one of those proportions I have proposed to be made use of, or any other; multiply the length and breadth of the room together, and that product multiply by the height, and the square-root of that sum will be the area of superficial content in feet, &c., of the light required.'

"Suppose a room, whose magnitude is the arithmetical proportion of 5, 4, and 3, and is 20 feet long, 16 feet broad, and 12 feet high, the cube or product of its length, breadth, and height multiplied together is 3,840, the square-root of which sum is 62 feet. If the height of the storey is 12 feet, as before mentioned, divide that 62 feet into three windows. Each window will contain 20 feet 8 inches of superficial light, and those will be found to be 3 feet 2 inches broad, and 6 feet 5 inches high, which are windows of two diameters.

"Let us now suppose another room on the same range, whose height is 12 feet, as the preceding example is, and its proportion shall be the cube. The product of that cube is 1,728, and its root is 41 feet 4 inches, or thereabouts. Divide that

41 feet 4 inches into two parts for two windows, and each will be 20 feet 8 inches of superficial light, and those will be two diameters in height, and the magnitude the same as the preceding room."

A rule of a very different character has been promulgated by the Local Government Board, in the "Model Bye-laws" issued by them for the use of sanitary authorities. These model bye-laws are issued as suggestions to local authorities, who have power to frame bye-laws in their respective districts; and the model No. 57 runs as follows:—

"Every person who shall erect a new building shall construct in every habitable room of such building one window at the least, opening directly into the external air, and he shall cause the total area of such window—or, if there be more than one, of the several windows—clear of the sash-frames, to be equal at the least to *one-tenth* of the floor area of such room."

Roughly measuring two rooms in my own London house, both of which I should consider well lighted, I find that one of them, with an eastward aspect, has a window opening of 36 square feet to about 225 square feet of floor space, and to rather more than 2,000 cubic feet of contents. The other, with a westward aspect, has 58 square feet of window opening to about 361 of floor space, and to rather more than 4,100 cubic feet of contents. In the smaller room, which has a window larger in proportion than the other, the lower third of the opening is filled by slightly-tinted cathedral glass, and green blinds are often drawn down over the upper third. In the larger room the whole window is filled with cathedral glass, and there are neither blinds nor curtains. Even in the full brightness of the afternoon sun there is here no excess of illumination; and, at other times, one would instinctively seek the vicinity of the window for any occupation requiring extreme accuracy of vision. According to the rule quoted by Gwilt from Morris, the smaller room should have 45 feet of window opening instead of 36, and the larger should have 64 instead of 58. According to the more moderate requirement of the Local Government Board, 22 feet would suffice for the smaller room, and 36 for the larger. The eastward window opens into the street, the westward into an open space of much greater extent; and I am disposed to think that, while the latter is not at all too large, but sufficient, the former might be diminished in size, not perhaps with any advantage, but certainly without any injury or inconvenience.

A consideration not to be lost sight of, in regulating the lighting of rooms, is that the eyes are protected, by their position in the head, by the eyebrows and eyelids, by the eyelashes, and by many prevailing forms of head-dress, against any excess of light coming to them, as natural light does come, from above; whilst they are almost entirely unprotected against any excess of light which comes up to them from below. It is for this reason that the glare reflected up from water, or from snow-covered or otherwise white ground, is often very distressing; insomuch that the inhabitants of countries in which much snow falls are accustomed to protect themselves by some kind of goggles. If we have low windows, so as to throw a strong light upon the floor of a room, and especially if we cover this floor with light or bright-coloured or reflecting surfaces, we expose the eyes of the occupants to similar unfavourable conditions. The low, or so-called French windows, opening like doors, are often convenient for purposes of entrance and exit, but in dwelling-rooms there is no occasion to fill the lower portions of them

with clear glass; and, if this is done, it is desirable to let the light so admitted fall upon some surface of dark colour and absorbent material. In all occupations, it is highly conducive to the distinctness of vision, and hence, to the comfort of the eyes themselves, that the chief light which falls upon them should proceed from the object looked at, and should be that which forms the picture of this object upon the retina. If an opposite condition obtains, and the eyes are receiving light at the same time from some other direction or some other source, the general diffused illumination of the retina which is thus produced serves to diminish the relative brightness and distinctness of the image, and so to render vision less certain. This would happen in the case of a person who was sitting reading near a low window, with a bright floor surface beneath. The eyes would receive not only the light reflected from the page, but also, being cast down to read, that which was reflected from the ground; and the latter, not being focussed upon the retina, would cover it with a diffused illumination, and would render the words and letters of the printed page less distinctly visible.

For pursuits which do not require accurate vision of small objects—such pursuits, for instance, as playing chess or draughts—any portion of an ordinarily lighted room should be sufficient, and any position of the window in relation to the eyes should be harmless; but when sustained accurate vision is required, as in such pursuits as reading, writing, or fine embroidery, the window should be on the left hand of the worker, and a little in advance of him. In this position, and in this position only, will the eyes receive the maximum of diffused light from the surface looked at, without being dazzled by the direct reflection of the solar beam. If the light is behind the worker, the body will intercept it, and it will be necessary to assume oblique and uncomfortable attitudes. If the light is on the right hand, the shadow of that hand will constantly obscure the work. Either of these positions, however, is better than a direct front light; unless this is derived from a window so high as to be quite above the line of sight when the eyes are lifted in a moderate degree. In all the pauses of occupation, the eyes are lifted instinctively; and they should always be lifted to a lesser degree of illumination than that which they receive while working. The lesser amount of illumination rests the nervous tissues of the retina, allows the pupil to expand, and is a moment of comparative repose for the whole organ. If, on the contrary, the eyes are lifted to encounter an increased illumination, as must always be the case when the window is directly in front of them, they are stimulated instead of being rested, their pupils contract by increased muscular effort, their nerve-tissues are excited instead of being soothed, and the intervals of labour, which ought to be periods of rest, are rendered periods of increased effort and fatigue.

When a facing window is so high above the line of sight that no inconvenience is experienced when the eyes are raised in the usual moderate degree, it will be apt to entail yet another inconvenience, by bringing them into the very track of the solar beam which is directly reflected from the surface of the object or of the table. In Fig. 182, A represents a person sitting opposite a window, W, which is placed at such a height that its light falls upon the table surface at an angle of 45 degrees, and hence, in accordance with the law of reflection, is reflected from the table at the same angle and in the same plane, just striking the eyes of the worker. In Fig. 183, on the contrary, the window is to the left, and here the directly reflected beam

passes in front of the worker, who receives only the diffused light which is reflected in various directions from the irregularities of the surface upon which it falls.

It seems to follow, from the foregoing considerations, that the sizes and positions

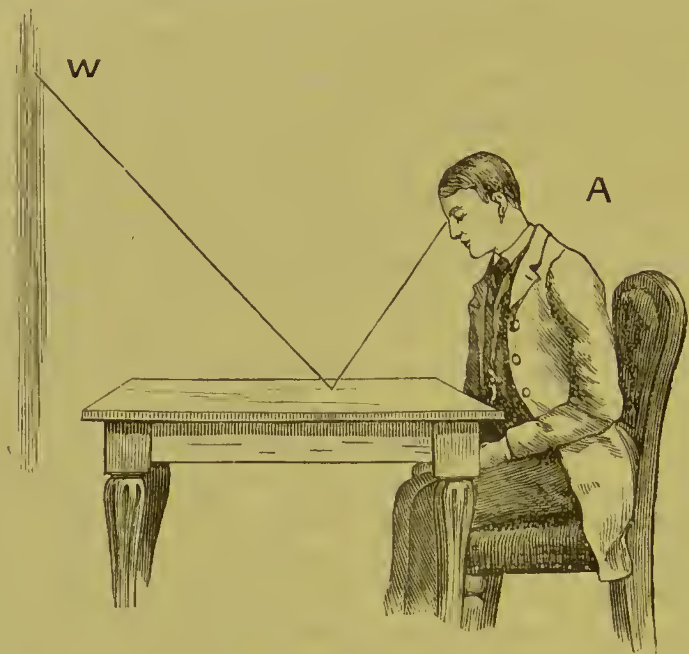


Fig. 182.—Front Illumination.

of the windows in ordinary sitting-rooms may safely be left to be controlled by customary usage and proportion; and that the adult occupants of such rooms will always be able to vary their own positions in relation to these windows in such a manner as to obtain light at convenient angles and in a sufficient degree. In the case

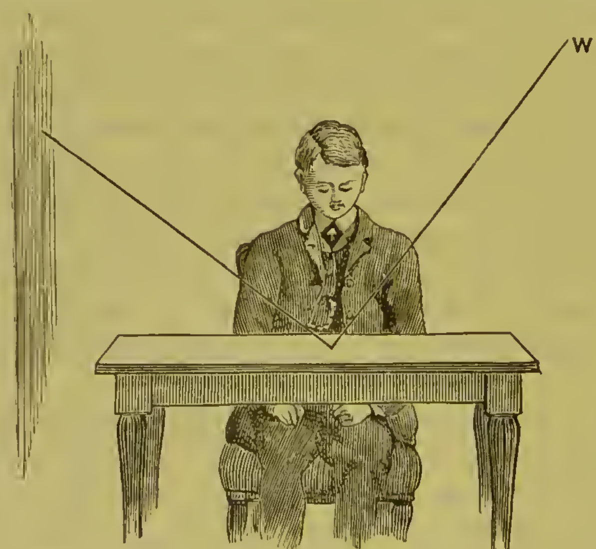


Fig. 183.—Left-hand Illumination.

of rooms appropriated to special purposes, however, and especially in school-rooms, either public or domestic, this spontaneous adaptation of means to ends should not be relied upon. In arranging a domestic school-room, parents cannot be too care-

ful to see that the window openings are sufficient; and as these, when once made, can seldom be altered, that the positions of the seats are arranged strictly with reference to them, and are not afterwards departed from. For children, the rule of plenty of light, and that plenty coming from the left front for all purposes of close application, should be invariable.

The amount of light received by any surface, and by which it is rendered visible, decreases as the square of the distance of that surface. The diagram in Fig. 184 represents a candle-flame as a source of light, with rays proceeding from it in right lines, and radiating equally in all directions. A given amount of this light falls

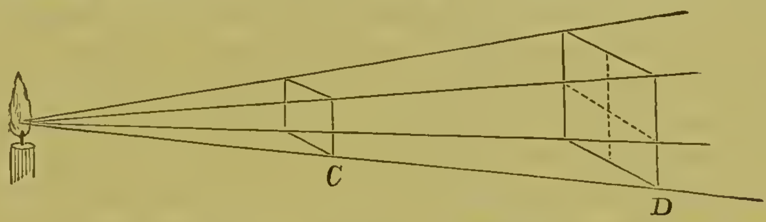


Fig. 184.—Distance and Illumination.

upon the screen C, which is four inches square and four inches from the flame. If the screen were removed, and the light were permitted to travel four inches farther to the second screen, D, it would cover a surface sixteen inches square, or four times the size of the preceding; and it is obvious that any space of the second screen equal in size to the first will only receive one-fourth of the light which the first received. If, instead of the screen, we have a printed or written page, at which a child is looking, and which he has to see by means of the light reflected from its surface, it is plain that the amount of this light which will fall upon the opening of his pupil, and so enter the eye, will be quadrupled by halving the distance at which the page is held. It follows that defective illumination compels the approximation of the object of vision; and in this way badly lighted school-rooms are manufactories of short sight. Short sight depends upon a faulty shape of the eyeball, in the direction of elongation from front to back; and this faulty shape is liable to be produced, and when produced is always increased, by the rolling inwards of the eyes which is required in order to fix them both upon an object which is held very near to them. Children at school often bring their faces too near to their books from other reasons than defective light: partly because their seats are too far away from their desks; partly because the muscles of the spine become tired of the effort of "sitting up," and suffer the head to droop; partly from other causes. But when the light is defective, an undue approximation of the object cannot be avoided, and cannot fail to produce or increase short sight. The whole subject has been very carefully investigated by Dr. Cohn, of Breslau, who examined the eyes of 10,000 school children in that and other German cities, and who found that short sight steadily increased, alike in the per-centage of cases and in the average degree of the affection, in proceeding from the infant to the finishing schools. As an evidence of the influence of defective light as a factor in its production, he found that the averages were higher, both as to number and degree, in schools situated in the narrow streets of old cities, and therefore badly lighted, than in any others. The same results have been obtained in Russia, America, and other countries, and will, no doubt, be

obtained in England whenever they are carefully looked for. The small and faulty type in which school-books are often printed adds to the requirement of good light for deciphering them; and no school-room should be held to be sufficiently lighted, and no room in any ordinary dwelling-house should be used for educational purposes, unless it is not only possible, but easy, to read the worst printed book used by the children at a minimum distance of fifteen inches from the eyes.

In public school-rooms, besides a faulty position of the windows, or of the desks in relation to them, we may often observe the additional disadvantages of small square or lozenge-shaped panes. These, when they are opposite the eyes, add greatly, in many persons, to the discomforts and inconveniences of a facing window. It is very common, or in some degree almost universal, for the surfaces of the eye to be curved somewhat differently in different directions, so that the boundary lines of squares and lozenges cannot all be seen at once with equal distinctness. When this is so, the irrepressible desire for clear images leads the eyes constantly to alter their adjustment, at the cost of muscular effort and of much fatigue, for the purpose of seeing these boundaries alternately; and hence, to some persons, a prospect of squares or lozenges becomes excessively fatiguing. If placed facing such windows, all the children of a class lose, as already explained, the repose of the eyes which they would obtain if they could look up from their books to a lower degree of illumination; and some of them are subjected to the increased effort and fatigue incidental to placing before them an object of vision which brings into prominence the consequences of a defect. The small panes are harmless when placed on the left of the pupils, provided the original window space was sufficient to afford the sacrifice of the large portion which, in glazing with squares or lozenges, must be occupied by opaque lead instead of by transparent glass.

Speaking generally, then, and with reference to cases in which the site affords perfect freedom of choice, a school-room should have numerous windows on its south side, and the children should sit at parallel desks, placed from south to north in the interspaces between the windows, and with their faces to the west. The extreme left-hand desks should not touch the wall in which the windows are placed, because if they did, those sitting at them would be too much in shadow; but the space at this side of the room should be utilised as a gangway. The advantages of south windows depend upon their admitting more sunshine than those in any other aspect; and if this sunshine should cause any annoyance from glare, the windows may be glazed with ground glass, which not only admits absolutely more light than clear glass, but also, by the multiple reflections from its surface, breaks up the direct and dazzling beam into diffused illumination. If a south aspect is not available, the desks should be so arranged as to keep the children with their left hands towards the light. If the windows are to the north, or in any aspect which does not admit sunshine during the hours of work, ground glass, though always desirable, will no longer be necessary.

When we have to deal with a room the window space of which is absolutely deficient, it is obvious that the best remedy for the resulting obscurity will be to enlarge the window. When this cannot be done, the next expedient is to economise the light that is admitted, and to render as much of it as possible available for the purposes of vision. To this end, we must remember that what we call a light-coloured surface is one which reflects, either from its surface or from immediately

beneath its surface, the larger portion of the light which falls upon it; while a dark-coloured surface is one which absorbs, and, by converting it into heat, retains, the larger portion of the light which falls upon it. Light-coloured objects, even when other than purely white, reflect absolutely from their surfaces light which is white, the very solar light unchanged in the proportions of its ingredients; and they reflect from immediately beneath their surfaces the same light, deprived of more or less of its elements, and therefore somewhat, even if only faintly, coloured. The secret of economising light is to line and furnish a room with light colours, and to render the surfaces superficially reflecting in the highest possible degree, so that more white light may be returned from them than would otherwise be the case. If we paper and paint the walls and ceiling with light colours, the rays which enter by the narrow window opening, instead of being absorbed by the first surface which receives them, will be reflected to and fro from surface to surface; and if we have the surfaces well varnished over the paint and paper, so as to render them glossy and reflecting, the surface reflections of white light will be still more considerable, and the lighting up of the room will be still more improved. Light-coloured furniture and draperies will be subservient to the same effect; and, in a room rendered dark by a small and lofty window opening, it may even be desirable to depart from the general rule already laid down, and to introduce light colours into the carpet.

A ready evidence of the practical value of this method is afforded by comparing the number of candles required to raise a room so furnished and fitted up to a comfortable standard of light for social purposes with the larger number which would be required in a room of the same dimensions, fitted up with dark walls, dark drapery, and dark furniture. The difference will be found so considerable as to outweigh the housewifely objection to light colours, on the ground of their tendency to "show dirt." For my own part, I do not think this tendency objectionable, because the more the dirt is shown, the more speedily is it likely to be cleared away; while, if the walls are varnished as advised, they may be washed down with a sponge and water, without the smallest injury, as often as circumstances may require.

When the light of a room is deficient, not because of the small size of the window space, or not solely from that reason, but also on account of defective outlook, as must be the case in the majority of narrow streets, especially of such as contain tall houses, the same recourse to light-coloured walls and light-coloured furniture may be had with equal advantage. We have here, however, other resources as well. Where the access of light is barred by an opposite wall, this should, whenever possible, be washed or painted of a light colour, and of course, by preference, white, so as to increase the amount of reflection from its surface; and in many cases benefit may be derived from the use of the suspended external mirrors introduced by Mr. Chappuis, under the name of "Daylight Reflectors," and extensively used in the narrow streets of the busiest part of the City of London. Much may also be done by pushing out the window so as to render it flush with the external surface of the wall, instead of being buried in a depression on that surface, and by filling it with ground glass. This plan was first recommended by Sir David Brewster, and his account of it may be given in his own words. He says:

"If, in a very narrow street or lane, we look out of a window with the eye in the same plane as the outer face of the wall in which the window is placed, we shall

see the whole of the sky by which the apartment can be illuminated. If we now withdraw the eye inwards, we shall gradually lose sight of the sky till it wholly disappears, which may take place when the eye is only six or eight inches from its first position. In such a case the apartment is illuminated only by the light reflected from the opposite wall, or the sides of the stones which form the window; because, if the glass of the window is six or eight inches within the wall, as it generally is, not a ray of light can fall upon it. If we now remove our window, and substitute another in which all the panes of glass are roughly ground on the outside, and flush with the outer wall, the light from the whole of the visible sky, and from the remotest part of the opposite wall, will be introduced into the apartment, reflected from the innumerable faces or facets which the grinding has produced. The whole window will appear as if the sky were beyond it, and from every point of this luminous surface light will radiate into all parts of the room." In other words, the more light your window can itself see, the more it will be able to transmit.

For lighting cellars, whether used for business purposes or as habitations, use should be made, whenever possible, of some of the various forms of lenses or prisms for insertion into pavement which have been invented during the last few years. By an arrangement of this kind, some of the gas and water subways of the newest streets in the City are very effectually illuminated; and since this was done, the contrivances themselves have been multiplied and improved.

CHAPTER XXXVIII.

REGULATION AND CONTROL OF DAYLIGHT ILLUMINATION.

Desirability of Sun-light—Windows with Open Prospect—Means of Preventing Vision through a Window—Cathedral Glass—Window-blinds—General Principles.

In considering the best aspect for windows, architects are limited, of course, by the requirements of the site upon which they build, by the declivities of the ground, by the view which is to be obtained in this or that direction, by the general arrangements and shape of the house, and by the extent to which its walls are presented to this or that side of the compass. It is obvious that all rooms cannot have the best aspect, and that many circumstances must determine the extent to which any of them can receive this advantage. It follows, however, from what has been already said with regard to the hygienic influences of light, and not of light merely, but of the actual solar ray, that it should be an object to introduce this ray wherever possible. The aspect of bed-rooms, regarded merely as sleeping apartments, does not appear to be of much importance, since they are chiefly occupied at times when the sun is absent; but, in any case of illness which promises to be of long duration, a room affording sunlight should always be selected, so that, in every house, at least one of the sleeping apartments should be so placed as to supply this want. Day nurseries, again, should have direct sunlight; and so should all rooms which are constantly inhabited. The potency of sunlight, however, although highly desirable from the point of view of those who attach importance to cleanliness and to the prevention of disease, is often in much disfavour with good housewives, since it tends to bleach nearly all coloured fabrics, and is even accused of putting fires out. Hence, in many dwellings the sun is treated as an enemy to be excluded. If a sitting-room has a south aspect, its window is furnished with semi-opaque blinds, and it is the special business of some one person to keep these drawn down during most of the day, lest the sun should spoil the curtains and the carpet. In London and other large cities, at least, carpets and curtains are abominations—mere dirt-traps, which become loaded with powdered filth of every description. Few people have any conception of the amount of dirt contained in an ordinary carpet, or of the extent to which what is commonly called "bronchitis," and is attributed to that mysterious agent, "a cold," is the direct result of drawing this dirt into the lungs after it has been beaten up by the trampling of feet. Curtains are even worse; for, although their vertical position does not afford the same facilities for lodgement as the horizontal position of the carpet, yet there is much harbour for dust between their folds, and this dust, if it is ever shaken out by housemaids, has no choice but to descend upon the horizontal surfaces of the room: partly, of course, upon tables and other articles of furniture, but chiefly upon the floor, there to await the next stirring from the feet of the occupants. If any one is sceptical on these points, let him have a sitting-room carpet swept with a common carpet broom, and then let the door be shut, and the room left quiet for

the dust to settle. Half-an-hour afterwards he will find a thick layer of it upon every horizontal surface; and if he possesses a microscope, and has the curiosity to examine this dust, and to see of what materials it is composed, I shall count upon him as a convert before the examination has been pushed very far. Household dust is, in fact, the powder of dried London mud, largely made up, of course, of finely-divided granite or wood from the pavements, but containing, in addition to these, particles of every description of decaying animal and vegetable matter. The droppings of horses and other animals, the entrails of fish, the outer leaves of cabbages, the bodies of dead cats, and the miscellaneous contents of dust-bins generally, all contribute their quota to the savoury compound; and it is to preserve a harbour for this compound that well-meaning people exclude the sun, so that he may not be guilty of spoiling their carpets.

Having digressed thus far, it is perhaps pardonable to extend the digression, and to suggest an alternative for the fabrics which by some are so much valued. In my own house the floors, both of sitting-rooms and bedrooms, are covered by oak parquetry, laid down by Messrs. Howard at the very moderate price of one shilling and twopence per foot, which is not the cost of a good carpet, and, for a room twenty feet square, amounts to just £23 6s. 8d. More elaborate patterns can be had at higher prices, but what I have mentioned is quite good enough for ordinary rooms, looks handsome, and wears for ever. It should not be waxed, but French polished; after which it may be wiped over or swept every day like the surface of a table, and once a month or so it should be wiped with spirit of turpentine, which not only cleans it perfectly, but also diffuses a fragrant and antiseptic vapour through the atmosphere. By opening the windows, anything which fastidious people could object to as "a smell of turpentine," is dissipated in an hour or so; but it must not be forgotten that all the terebinthinate vapours are extremely wholesome. A loosely woven rug or two, such as are sold under the name of Scinde rugs, but which, for anything I know to the contrary, may be made in Yorkshire, will serve to break the monotony of the floor surface. These rugs hold but little dust, may be shaken outside the door every morning, and are so cheap that there need be no compunction about throwing them away when soiled, and buying new ones. The great question of curtains admits of a still more easy solution; for it is only necessary to bestow some taste and skill upon the painting and decoration of the woodwork around the windows, in order to obtain ornamental surfaces which no one who possessed them would wish to cover up and conceal. Where this cannot be done, let the curtains be of some white fabric of a semi-transparent character, such as lace or gauze, which will "show the dirt" to such an extent that they must be sent once a fortnight to the washtub. Assuming that it may sometimes be desirable to moderate or regulate the admission of light, this may be done by roller blinds of fitting material, and of colour suited to their surroundings. In some of my own rooms, even these blinds are not required, the windows being filled with slightly tinted cathedral glass, so that the sunlight which passes through them is broken and diffused in its course, and produces no unpleasant effect by its brightness.

We are naturally led on, from this point, to the consideration of window glass; and it will be at once apparent that windows may be divided, as regards glazing, into several classes. There are windows which command a desirable prospect, windows which are valuable for lighting purposes, but which command only an

undesirable prospect; and there are windows which are only wanted as sources of light, in rooms the occupants of which are not required to look out of them. The last division would include those of many schoolrooms and workrooms opening upon streets, in which it would be an object to exclude the sight of any passing objects of a kind calculated to distract the attention of the inmates.

Where the prospect from a window is itself desirable, and when it is also desirable that this prospect should be seen and enjoyed by those within, glass of the most pellucid clearness is of course to be preferred. Common window glass, as everybody knows, fulfils what may be described as the ordinary requirements in this particular, but its slightly greenish tint, and the occasional flaws upon its surface, are sufficient to declare the fact of its presence, and to show that something intervenes between the prospect and the spectator. Wherever the increased cost is not prohibitive, plate-glass is much to be preferred; not only because its transparency is such as to render it practically invisible, but also on account of the value of its greater thickness in preventing that rapid escape of the heat of a room which is apt to occur through thin window glass. It is also less easily penetrated by sound, an advantage in noisy streets and thoroughfares, and it materially strengthens windows against the attacks of burglars, a matter not to be altogether lost sight of by the builders of suburban residences. By some, slightly tinted transparent glass is preferred, in order that it may cast a certain glow and refulgence over the landscape; and for this purpose a light purple or mauve has been most employed. The effect thus produced is no doubt pleasing for a time, and as a matter of variety from more customary impressions; but, in fitting up a house, it is necessary to remember that its rooms are not merely for the accommodation and delectation of chance visitors, but that they are to be lived in, year after year, and in all conditions of light, of sky, and of atmosphere. In that which is always with us, nothing is so permanently soothing and pleasant as simplicity, and anything which widely departs from simplicity never fails, in the long run, to fatigue both the eye and the attention. Nature's own harmony of colour, in garden or landscape, will be a source of more lasting pleasure that the same outlines when seen through a transforming medium; and, in accordance with the rule laid down by Professor Barff, and already mentioned, the tints which are the immediate results of the dispersion of sunlight, and which, if recombined, would blend in whiteness, are more restful and pleasing, when long regarded, than any others by which they can be replaced.

If, as must often be the case in London and other large towns, especially with back windows, the view commanded by one which cannot be dispensed with as a source of light is otherwise of an unpleasant character; the prospect of a mews, for example, or of the backs of the houses in an adjacent street, the problem of admitting the light while the view is excluded may be solved in various ways. For rooms which are not inhabited, such as bath-rooms and the like, in which, moreover, it is often desirable to exclude not only a look out, but also the power of others to look in, any of the numerous cheap forms of fluted or ground glass will suffice. All such glass, as has been already mentioned in a quotation from Sir David Brewster, increases the amount of light which finds entrance through the window opening; and the precise texture of its surface is a matter of little or no moment. Where ornament is desirable, either from within or from without, what is called

embossed glass will supply the requirement. In this, a fleur de lis, a diaper, a fret, or some other simple pattern, not large enough or continuous enough to produce a practical transparency, is sunk or stamped upon the sheet of glass; and then the remainder or raised portion is ground so as to transmit light but to obstruct vision. Such glass is made in thick sheets resembling plate, is very moderate in cost, and has the advantage, like plate, of retaining the warmth of the interior. It is also so strong as to be scarcely at all liable to domestic breakage, and will withstand the shock of a child's hard ball, even if thrown with considerable force.

When it is desired to exclude the view from the window of a sitting-room, the best material, beyond all question, is slightly tinted cathedral glass. The tint must not be strong, or it will in time be wearisome to the eye; and the colours selected must be such as to produce a white light combination. Cathedral glass is usually cut into pieces about three inches square, which are mounted in lead; and, assuming the original window to have large panes, the best method of proceeding is to line each of these with a compound pane made up of the small pieces, and fixed to the sash bars by screws or slight wooden fillets, so arranged that the coloured glass can be taken down whenever necessary, to be cleaned itself, and to allow the transparent glass behind it to be cleaned also. A very excellent and permanently pleasing effect may be produced by making each compound pane of alternate squares of a very light tender green and soft grey; the small quantity of brighter colour required being introduced in a narrow border formed of strips of red, yellow, and blue in rotation. Such compound panes can be supplied at about four shillings the superficial foot. The texture of the cathedral glass is such that it does not diminish, nay, it probably somewhat increases, interior illumination; but the light which it transmits is so broken in its passage that there is no definite beam, even in direct sunlight, and consequently no glare or unpleasant reflection from any part of the room. With such a window there can never be any occasion to draw curtains or to pull down blinds; and hence these dirt traps may be omitted from the scheme of furnishing. Where a greater amount of ornament is desired, or where it would be in harmony with the rest of the apartment, the squares may be enriched by patterns painted upon them and burnt in. A simple diaper, a fleur de lis, a Tudor rose, a sprig of leaves and blossom, either natural or conventional, may thus be executed at a moderate expense; or the centres of the panes may be occupied by something more ambitious, as by armorial bearings, by figures, or by heads, and the lead mounting may be altered in appearance by being gilt. On the whole, however, and for ordinary houses, I still maintain that simplicity is best.

As seen from the exterior, the effect of the cathedral glass, if not beautiful, is at least in no way conspicuous enough to be unpleasing; and the same applies to the effect which it produces from the interior, when the room is lighted up by artificial means. It is then to all intents and purposes invisible, and there is nothing which would call attention to such a window at all.

I have often heard it said, as an unanswerable objection to my proposal to abolish window curtains, that they keep a room warm; that an "unprotected" window is a source from which a constant current of cold air rushes towards the fire, chilling on its road all those occupants of the room whom it encounters; and that there is nothing so "cosy," which I should translate "stuffy," as to draw the window curtains on a winter's night, and then to sit around the cheerful blaze of the

fire. If a house has been "run up" by a speculative builder, if the window-frames do not fit the sashes, and if the absence of any designed arrangement for the admission of air receives a large compensation from what may be called accidental or crevice ventilation, then, no doubt, curtains may be used with advantage in the manner described. If the window-glass is very thin, a mere partition through which the external and internal temperatures are perpetually trying to equalise themselves, then also the argument may hold good in some degree. But, if the sashes fit properly, and the glass is of proper thickness, no current of cold air from the window will exist, and the inner panes of cathedral glass are great additions to comfort in this respect. They not only double, or more than double, the thickness of the window, but they present this thickness in two separate layers, between which the most complete non-conductor, a layer of still air, is retained. In order to retain this completely, the edges of the wooden fillets may be united to the compound panes by putty, and then the two interior or opposed surfaces of glass, being closed against the entrance of dirt, will not require cleaning.

The same compound panes may be used with great advantage to line the lower halves or lower portions of ordinary windows, in lieu of blinds of any other description. They entirely conceal the occupants of a room from external passers-by, and they are much more in harmony with the notion of a window than any of the bits of canework or basket-work, the framed sheets of wire gauze, the cases of ferns and butterflies, and the various other contrivances too numerous to mention, by which the lower portions of many ground-floor windows are customarily disfigured. Still more are they to be preferred, for bed-rooms, to the draggle-tailed abominations known as muslin blinds, which, from the outside, never look tidy unless an upholsterer's man is employed to come once a week to change and fix them. When left to the tender mercies of the average housewife or housemaid, and changed only at her discretion, they are not to be seen from the street without a shudder. The blinds of cathedral glass can be washed in five minutes with a sponge and water, they are always neat-looking from the exterior, and their soft light is always pleasant and harmonious to those within. In this account of them, however, I must be understood to speak only of the small squares of soft colour, and not of the more ambitious performances, containing figures of sprawling nymphs, or heads, "taken from the antique," of which there are a few specimens to be seen in London thoroughfares. Neither are my observations intended to apply to those cases in which the lead mounting of the small squares is gilded. The intense "brassiness" of aspect which is presented by gilding in such a situation is something almost too painful to contemplate.

The selection of roller blinds for the situations—and they are very numerous—in which such blinds are beneficial, is a matter which should receive careful attention. The materials available for the purpose have much increased in number, and also in beauty and fitness, during the last few years, and the old-fashioned white roller blind is probably now only to be found in a few badly-furnished inns or remote country-houses. The colour selected must necessarily be governed, in the majority of cases, by that of the rest of the furniture or decorations of the room, with which, of course, the blinds should be in harmony; but the material should always be of sufficient thickness to be effectual as an impediment to the passage of light, and to damp or exclude it in a decided manner. The white blind conspicuously fails in

this respect, and, indeed, scarcely answers any other purpose than to prevent persons on the outside of a window from seeing into the room. A good and comparatively opaque blind is made of a sort of holland, dyed of a dark green, buff, or red colour, but perhaps the best material is either tammy or what is known as "tick," a fabric which bears some resemblance to ordinary bed-ticking. A perfectly opaque blind has recently been introduced, made of a material called "empire cloth," but I have no experience of its qualities. The colour of a blind is, I think, a matter of small consequence, as long as the tissue from which it is made is of sufficient thickness in all its parts. We often see striped materials which do not fulfil this condition, and which are very objectionable. A blind striped with white and some darker colour, arranged in longitudinal bars, is quite harmless as long as the white portions do not admit more light than the rest; but, if it presents to the eye an alternation of light and dark, as well as of colour, it soon becomes disagreeable and fatiguing. Theoretically, blinds which are dark green or blue should be more soothing to the sight than those which are red or yellow, but I doubt whether this will be found to be the case in practice, at least in any important degree. I have lived a good deal in rooms with red blinds, and also in rooms with buff or yellow blinds, and never perceived the smallest inconvenience from either.

It must be remembered that blinds are required to be of different qualities in accordance with the rooms in which they are placed, or, rather, in accordance with the several purposes to which those rooms are devoted.

In ordinary sitting-rooms, the chief use of a blind is occasionally to subdue the direct solar light, when it shines in through a transparent window in such a manner as to be dazzling to the occupants, and for this purpose a comparatively thin material will be sufficient. We have seen already that free exposure to the solar light is good and healthful, and therefore the less of this light we exclude the better, so long as the requirements of comfort are fulfilled. A blind of light semi-transparent tammy, preferably, perhaps, of a blue or green colour, will be sufficient to allow ordinary occupations to be carried on in any part of the room, without interference, or distress of the eyes, by reason of solar glare. As already written, I have no sympathy with those good housewives who would pull down opaque blinds, and exclude as much light as possible from themselves and from their families in order to protect a carpet which would be far better discarded.

In workrooms, or places in which the eyes are used continuously, instead of in the intermitting fashion of domestic life, and in which the aspect of the windows is such that at certain times of the day the sunlight not only streams in at certain windows, but also falls directly upon the tables or the eyes of the workers, the object of the blinds should be to convert this direct sunlight into the semblance of diffused daylight, and to preserve, as much as possible, uniformity of illumination. For this purpose, the blinds should be of uniform tint, dark enough, but not too dark, and permitting the somewhat free passage of the rays which, nevertheless, they completely diffuse or scatter. No certain rule can be laid down, as much must depend upon the size of the window opening, its distance from the seats of the workers, its precise aspect, and other similar considerations. An employer or a teacher who wishes for good work must take the trouble to satisfy himself that the best attainable conditions of illumination are secured, by the exclusion of light

when necessary as well as by its admission ; and the crucial test, in every case, will be supplied by the comfort or discomfort of the workers.

But the place where the blind most requires to be considered, and to be effectual, is a bedroom, especially one facing towards the east, and in which the shape and other peculiarities of the room render it convenient to place the bed opposite the window or windows. In the conditions of modern civilisation, there are very few persons who can afford to be wakened, or even to pass from sound into light slumber, at daybreak, and yet this effect is often produced by the morning light, imperfectly excluded from the apartment. Darkness is a most important aid to sound and refreshing sleep, and few things are more distressing, to anyone accustomed to a well-darkened bedroom, than to be aroused by the sunlight shining in upon a strange bed, at an hour when none of the inmates of the house are stirring. For a bedroom with its bed facing a window, and especially an east window, into which the morning sun shines, not only should the blinds be of dark and opaque material, and so carefully fitted that no lines of bright light find admission on either side of them, but the aid of shutters should also, generally speaking, be obtained. It is always easy to provide the means of being awakened at any necessary hour ; it is seldom possible to resume the thread of a sleep which has been prematurely interrupted. An incidental advantage of using bedroom shutters, and one not to be despised, is that when they are shut and opened every day, there is less than the ordinary probability of accumulations of dirt being suffered to rest undisturbed behind them. Of course, the artificial darkness must be exchanged, as soon as the period allotted to sleep is over, for the freest possible admission of sunlight, in order to obtain its purifying influence. When the bed can be so placed, in relation to the windows, that the morning light does not fall directly upon the face of the sleeper, it is not necessary to insist upon such rigorous exclusion.

To sum up what has been said, the general principles on which to regulate the lighting of rooms are mainly these. The window space should be ample ; the windows so situated as to allow desks or work-tables to be placed in such a manner that the occupants have the chief light on the left front, or else so high above them that the eyes when raised from the work do not receive an increased illumination. When facing windows are inevitable, they should be glazed with large panes, not with small parallelograms, the outlines of which are distressing to many eyes, and they should be well furnished with good blinds for the sake of toning down the light at periods when it would otherwise be excessive, and of keeping it approximately equal at different times of the day and different seasons of the year. When the admission of light is required without an outlook, the various forms of ground or rolled glass should be used for rooms in which ornament is not essential ; and for others the same purpose may be better fulfilled by the use of cathedral glass, tinted in soft colours and low tones.

CHAPTER XXXIX.

ARTIFICIAL ILLUMINATION—INCANDESCENCE—NATURAL AND ARTIFICIAL LIGHT COMPARED.

Incandescence—General Nature of the Illumination from a Flame—Incandescence caused by an Electric Current—General Characteristics of Artificial Light—Injurious Effects of Ordinary Artificial Light—Peculiarities of the Electric Light.

In the English climate, and in the existing state of civilisation, the light which is derived immediately from the sun supplies but a comparatively small portion of the wants of the inhabitants; and there are many of the busiest and most active hours of life in which we are entirely dependent upon artificial substitutes. With sunlight, our powers are limited to regulating the conditions of its admission, and to modifying its character by the subtraction of some of its parts; but artificial light, as far as its properties extend, is much more under our control. It is therefore highly important that we should select such forms of it as are most conducive to the welfare of the eyes, to accurate and sustained vision, and to the purity of the atmosphere of our dwellings. On all these points there are many elements to be considered.

Artificial light is obtained by raising some substance to such a temperature that it becomes incandescent, and this is accomplished in various ways; the colour of the resulting light bearing a general relation to the elevation of the temperature. A heated bar of iron, even while it is still black, imparts to the surrounding ether a movement like that of the large waves beyond the visible red of the spectrum, and this movement is felt as warmth. As the temperature of the iron rises, the waves increase in rapidity of recurrence and diminish in length; until, in time, they become visible in the form of red light, and we say that the iron is red hot. The temperature still rising, white heat is attained; or, in other words, the vibrations assume sufficient rapidity to produce the other elements of the solar spectrum, and the commingling of all the waves is felt as white light.

Until a comparatively recent period, the incandescence required for artificial illumination was obtained exclusively by the utilisation of the heat developed during the occurrence of chemical change; but to this must now be added that which is derived from the impeded conduction of an electric current.

The chemical change which is accompanied by the development of heat and light is, most commonly, oxidation; and the substances which would burn in the presence of oxygen, under favourable conditions, are very numerous. The luminosity which they yield when burning does not depend only upon the temperature which is produced, but also upon the character of the particles of the resulting oxide, and upon their capacity for becoming incandescent. If we burn pure hydrogen, the flame is intensely hot, but is only faintly luminous, because the resulting oxide is water, and the particles of water are ill-adapted for the display of luminosity. If, on the other hand, we burn a piece of magnesium or zinc wire, the luminosity is intense, because the resulting oxide of magnesium or of zinc is capable of being raised to a

white heat without being thereby either dissipated or destroyed. Magnesium and zinc, however, like many other substances which yield an abundant luminosity, are not manageable in practice, on account of the difficulty of dealing with the bulky products of their combustion. The oxide of either metal, after being for a moment heated to whiteness in the flame, would fall out of it by the action of gravity, and would be deposited as a white powder below: while yet another objection would arise from the very rapid wasting of the metallic fuel. In practice, the best results obtainable by combustion are those yielded by burning mixtures or compounds of hydrogen and carbon. In these, the affinity of hydrogen for oxygen being greater than that of carbon, the whole of the oxygen immediately surrounding the flame is at first seized upon by the hydrogen, intense heat with faint luminosity is produced, and the carbon is set free. The liberated carbon, which is in a state of extremely fine division, becomes heated to incandescence in the hydrogen flame, which it renders brightly luminous; and then, instead of falling as the oxides of zinc or of magnesium would do, it finds a supply of oxygen for itself outside of the region within which the claims of the hydrogen are satisfied, and is itself oxidised in its turn, and converted into carbonic acid or carbonic oxide, the latter only very sparingly. The main products of such combustion, therefore, are carbonic acid gas and water; and combustion vitiates the atmosphere in two ways, first, by withdrawing oxygen, secondly, by producing carbonic acid.

Fig. 185.

The changes above described, as they occur in a common candle, may be illustrated by the diagram in Fig. 185. The heat of the flame liquefies the portion of the candle immediately beneath it, and thus forms a little cup or reservoir of hot oil. This oil ascends through the fibres of the wick by capillary attraction, and reaches the interior of the flame, where, being screened from oxygen, it is subjected to a kind of distillation, and is converted into gas. The hydrogen element of this gas burns in the manner already described, and the carbon element, first heated to whiteness or redness in the hydrogen flame, is oxidised immediately around it. In course of time, as the fat is consumed, its level descends; and the charred and partially consumed wick would therefore rise to a greater height in the flame, lowering the temperature by its presence, and diminishing the combustion and the consequent luminosity. This difficulty, which our forefathers overcame by the use of snuffers, is now obviated by causing the wick to curl outwards to the edge of the flame, where the ash of its terminal portion constantly either falls or is itself oxidised.

In the forms of incandescence which constitute what is known as the electric light, the heat is obtained by the impeded conduction of an electric current. The process which is described as conduction is, no doubt, the excessively rapid propagation of wave movement through the constituent molecules of the conducting substance; and the fact that impeded or arrested motion shows itself in the form of heat is one of the elementary truths of physics. If an electric current is passing easily through a wire of given sectional area, and if we interrupt its progress by introducing into the circuit a piece of wire of much smaller sectional area, the latter instantly becomes heated in a degree corresponding to the impediment which it offers

to the current. In the application of the heat thus obtained to practical purposes, it is usual to have the thin wire of platinum, on account of the resistance which it offers to fusion; thin wires of any metal of ordinary fusibility being liable to be rapidly melted, with consequent destruction of the electric circuit. The glowing platinum wire has long been employed for many purposes, in surgery as a cautery, and in public buildings as a means of lighting gas jets which are not conveniently accessible in the ordinary way.

When an electric current of sufficient power passes through a circuit which is partly made up of two rods of carbon, the extremities of which are in contact, and when these extremities, during the passage of the current, are drawn somewhat asunder, the current will leap across the intervening space, so long as this is not too considerable. The space in question will then be occupied by atmospheric air and other gaseous matter, containing a quantity of carbon in exceedingly minute division; and the resistance thus offered to the passage of the current produces sufficient heat to raise the carbon and other particles to a state of brilliant incandescence. The luminous track thus formed is called the electric arc, and is the source of light in several well-known forms of electric lamp. It is subject to the disadvantage that the resistance of the gaseous matter to the current is not constant, but varying perpetually; and, as the degree of luminosity varies inversely as the resistance, the light appears to flicker from one moment to the next. Moreover, the carbon rods being consumed by the disruption of their terminal portions, the interval between them constantly increases. After it has passed a certain limit, the light wanes; and, if this limit were much exceeded, the current would no longer be able to cross the interval, the circuit would be broken, and the light would go out. It is therefore necessary to provide, by clockwork or other means, for the regular approximation of the rods as fast as they are consumed; and the practical effect of this necessity is that, beyond the constant liability to flicker, the light wanes a little from its brightest as the rods are consumed, and at short intervals of time suddenly brightens up as they are once more pushed together.

On account of the inconveniences hence arising, and also on account of the overwhelming brilliancy of the light being such as to render it unsuitable for ordinary rooms and other limited areas, it has long been an object of desire to find some solid substance, which could be rendered incandescent, as a substitute for the gaseous incandescence of the electric arc. The chief difficulty was the liability to fusion of almost all the materials which were at first employed for the purpose, and among which platinum and iridium were the most important. After a time it was suggested, I think by Mr. Edison, that a slender rod of solid carbon, supported in a vacuum, might be used as the incandescent material; and he employed for this purpose a small horse-shoe shaped piece of charred cardboard, inclosed within a glass globe exhausted of air, with such results as to lead to a grave announcement that the difficulties of electric lighting for domestic uses had been overcome. As it turned out, this announcement was at least premature; but several other experimenters have since been working in the same direction, and with the general result that slender loops of carbon, rendered incandescent in vacuo, or in sealed globes containing some gas which is not a supporter of combustion, are expected to furnish, at least for domestic purposes, the electric light of the immediate future. To this subject it will be necessary to return hereafter, the object in this place being

merely to explain the principles on which the various forms of artificial light depend.

Putting aside electricity for the moment, and speaking of actual practice, it may be said that all the other forms of artificial light in use are produced by the combustion of some compound of hydrogen and carbon, previously volatilised or brought into the gaseous condition. In burning what is commonly called gas, this is the natural physical condition of the fuel; in burning oil or fat the volatilisation is effected in the immediate vicinity of the flame, by the heat given out by the combustion of the particles last consumed. Combustion is a chemical change, which consists essentially of the decomposition of the burning hydro-carbon into its two elements, both of which unite with the oxygen of the atmosphere, the hydrogen immediately to form water, the carbon ultimately to form carbonic acid. When the hydro-carbon is impure, as, for example, when gas or oil contains sulphur, any impurities present will also, as a rule, be more or less completely oxidised, and will produce chemical compounds according to their several natures and properties.

The carbon which is found in the inorganic kingdom, whether in a pure form, as graphite, in solid combinations, as coal, or in liquid combinations, such as petroleum and other so-called mineral oils, has all been originally withdrawn from the atmosphere by vegetable growth, under the stimulus of solar light; and the hydro-carbons of the animal kingdom, such as the various forms of fat, have derived their carbon from the employment of vegetable matter as an alimentary material; so that, in point of fact, all the forms of combustion by which we ordinarily produce light and heat are nothing but reversals, on a small scale, of the solar action of former periods, and all artificial light is derived, at least indirectly, from the sun. The cheerful glow and the genial warmth of our coal fires are but the re-appearance, in those forms, of the solar force which caused the growth of a primeval forest, and which has since been engaged, until liberated by human agency, in binding together the elements of which the coal was composed.

Still excepting the electric light, nearly all the other forms have this common characteristic, derived from the imperfect incandescence of the carbon furnished by their several fuels, that they are poor in blue. The heat furnished by the hydrogen flame, as ordinarily produced, is not sufficient to raise the carbon particles to a temperature at which they will yield the solar proportion of violet rays. If we throw the spectrum of any artificial light upon a screen, and compare it with the solar spectrum, we shall find that the former presents a fair approach to the latter at the red end, but that it is cut off prematurely at the violet end; the differences between different kinds of flame in the amount of their violet being considerable, but, even in the best of them, the deficiency being very marked. The necessary consequence of this poverty in violet is that ordinary artificial light is of a reddish, yellow, or orange colour when compared with sunlight; and that hence it disguises, more or less, the natural colours of all the objects which it displays. It does this in two ways: first, by not supplying light enough for those surfaces which absorb red and green and reflect violet; secondly, by showing all colours against an environment of yellow instead of an environment of white. By candle or lamp-light, for example, yellow in delicate shades can scarcely be distinguished from adjacent white; but this is chiefly because the white itself is made to appear yellow by the composition of the light which falls upon it, so that no

effect of contrast is produced. The eye is really comparing yellow with yellow, and failing to tell them apart. It is not, in truth, comparing yellow with white at all. No surface can look truly white unless white light falls upon it, because no other will allow all the elements the spectrum to be reflected in the proper proportions.

Another characteristic of artificial light, still excepting the electric, is its feeble illuminating power when compared with even weak diffused daylight. If we take a powerful or even brilliant flame, and place it upon a table in the middle of a moderate-sized room, we shall find it difficult or impossible to read fine print in the more remote portions; although this can be done in any part of the room even on a dull or cloudy day. The reason of this seems to be partly the lack of defining power which is consequent upon falseness of colour, partly an absolute inadequacy of all the elements of the spectrum.

A third characteristic of artificial light, still excepting the electric, is furnished by its heating and drying properties. The light of the sun, originally rich in heat rays, scarcely ever comes direct to the eye from its source. We receive it only after innumerable reflections from atmospheric particles, from watery vapour, from masses of cloud, from trees, from buildings, from the surface of the ground, from vegetation generally, from all the animate and inanimate objects around us. At each reflection it parts with a portion of its heat; and diffused daylight, as it reaches our eyes, can scarcely be said to have any manifest heating qualities left. Even when it is sufficient to dazzle by its brightness, it does not occasion the sensations of dryness and scorching with which those who work by badly-arranged artificial light are only too familiar.

With artificial light, on the other hand, there is no distance to travel, and there are not any, or there are scarcely any, intermediate reflections. Where defining power is required, the source of light must be near to the eyes and to the objects of vision, and it must often fall upon the former after reflection only from the latter. Even if we may assume that it is originally as comparatively poor in heat rays as in illumination, still it loses nothing; and falls upon the surface of the eye, or enters its interior, in almost precisely the state in which it proceeded from its immediate source. There is reason to believe that the excess of heat present with artificial light may in some circumstances be injurious to the retina, and it is nearly always a source of irritation to the eye-surfaces. The source of light is a little stove, which rapidly dries the air surrounding it, and this air, so dried, will feed itself with moisture from every available source. Such a source is often furnished by the moisture of the secretions which lubricate the eye-surfaces, and the drying-up of this moisture leads to an increased formation, to an influx of blood, and to a generally irritable state of the membrane which covers the front of the eyeball and lines the lids.

A final characteristic of artificial light, from which the electric cannot be excluded, is that it comes to us from some single definite local source or direction, instead of being diffused universally. The solar light is everywhere—it envelops and surrounds us. The light of a lamp or candle comes from the spot where the lamp or candle stands, and diminishes in intensity as the square of our distance from that spot. Hence, if there be a preferable position for artificial light, in relation to the eyes—as for all working purposes we shall hereafter see that there

is—this position, in a roomful of people, must be monopolised by one, or at best by a few, of them, and the light must be in its worst position with reference to others. Moreover, the artificial light is generally more or less flickering and unsteady, varying in intensity from minute to minute, and subjecting the eyes to constant changes of the illumination under which they are compelled to work. All these conditions of its application call for separate study on the part of those who are required to employ it continuously.

The electric light, on the contrary, as will have been gathered from the short account already given of the manner in which it is produced, stands in many respects alone. It contains an abundance of violet, as well as of the other colours of the spectrum, so that, in good examples, it differs very little from sunlight in its illuminating and defining power. Although given off by matter in a high state of incandescence, the amount of this matter is small, and hence the heat which attends it is much less than that of the common hydrogen flames in which carbon is consumed. When the electric arc is employed, carbon is dissipated and oxidised at the expense of the oxygen of the atmosphere, which to this extent is vitiated; but even then the degree of this vitiation is insignificant when compared with the amount of light produced, and there are no other noxious products of the flame. If the light is furnished by some solid incandescent material, more especially when this is carbon enclosed within a sealed receptacle, there is no vitiation of the atmosphere at all.

CHAPTER XL.

THE ELECTRIC LIGHT.

Advantages of the Electric Light—Methods of Avoiding the Direct Brilliancy of the Arc Light—Possible Effects of the Copious Violet Rays—General Nature of an "Installation"—Various Electric Lamps—Unsettled Position of the Question.

As regards the character of the illumination, the advantages of the electric light over all other artificial illuminants are numerous and striking. As above stated, the light is almost precisely like sunlight, the spectra of the two being practically the same, while the brilliancy leaves nothing to be desired. When suitably arranged, the light has all the clearness and defining power of daylight, and can scarcely be distinguished from it. The electric arc is only objectionable when it is so near the eyes that the directness and brilliancy of the beam become distressing; and, in order to meet this difficulty, it is necessary to arrange for the production of multiple reflections, by which the light will be treated before it reaches the eyes of the worker, much as sunlight is treated by the numerous intervening objects upon which it falls, and by which it is deprived, not only of some of its heat waves, but also of some portion of its pure light vibrations, and is thus somewhat altered in colour. The precise way in which the intermediate reflections can be obtained must differ, of course, with the position of the light and with the purposes to which it is to be applied, but an interesting illustration of one method is to be seen at the studio of Mr. Van der Weyde, in Regent Street, where the electric arc is applied to the uses of the photographer, and where the sitter is placed in a flood of light of such brilliancy and actinic power as to produce a photograph after only ten seconds' exposure, and yet without the slightest dazzling being produced, so that even nervous persons feel no inclination to close their eyelids or otherwise to make grimaces for the purpose of excluding excessive illumination. Whilst being photographed in this manner, it is as easy to read the smallest print, or to discern the smallest object, as it would be to do either in the neighbourhood of a good window in broad daylight. Mr. Van der Weyde places the electric arc in the focus of a parabolic reflector, and screens it from the sitter by the interposition of a small opaque disc. The surface of the reflector is white, very slightly tinted with ultramarine blue, and the parallel beam which proceeds from this surface is made to pass through a Fresnel's lens, of just sufficient convexity to efface the shadow of the disc by the convergence which it produces. A method sometimes employed for the illumination of a large room has been to place the electric arc near the ceiling, with a horizontal opaque screen, of appropriate size, extended beneath it, and forming a sort of under-ceiling. This screen would have a white upper surface, which would receive the electric light, and reflect it up to the true ceiling, from whence it would be reflected again to the upper portions of the walls, and would only reach the eyes of the occupants of the room after being diffused abroad, somewhat as sunlight is diffused by the multiple reflections of nature. All arrangements of this kind, however, will be rendered unnecessary whenever good lamps of sufficiently small size and power can be brought into practical operation.

Besides its advantages as an illuminant, the chemical and sanitary advantages of the electric light are scarcely less conspicuous. It will afford absolute freedom from the many impurities contained in ordinary gases and oils, and from the many noxious vapours and foul smells which they so often evolve. Its merits may be summed up by saying that it is the best known illuminant, that it gives but little heat, and that it may be so arranged as to consume no oxygen, and to yield absolutely nothing that is noxious or destructive to either organic or inorganic substances. Not only the human lungs are unharmed by it, but also the books, pictures, and furniture, which often sustain such serious injury from the indirect effects of other methods of lighting.

There is one point, however, with regard to the electric light, for the determination of which experience of somewhat long duration, and embracing many individuals, seems to be required. It resembles solar light, and differs from artificial light of all other kinds, in being rich not only in violet rays, but also in the ultra-violet rays, beyond the visible limits of the blue end of the spectrum, by which chemical and vital activity are so conspicuously promoted. Dr. Siemens has recently found that plants will grow and thrive, and bear flowers and ripen fruit, as rapidly under electric light as under sunshine; and, indeed, that they may be made to grow and to continue other vital processes uninterruptedly and continuously, and without their usual nightly rest, if they are exposed to the electric light as soon as daylight is withdrawn from them. In man and animals, no doubt, the stimulus to vital action afforded by light is in great measure due to the violet or ultra-violet rays, and is only in operation during the period of sunshine, ordinary artificial light not affording the necessary stimulus. Assuming this, and assuming that in man and animals, as in plants, the electric light is capable of replacing sunlight in this respect, we have yet to learn whether the effects of prolonged exposure to such light will be hurtful in any, and, if so, in what circumstances. In our northern climate, the natural amount of exposure to the ultra-violet is not prolonged, and is broken by long nightly interruptions. In winter especially, and certainly among the educated classes, most people are exposed to artificial light for as long a period, in each twenty-four hours, as they are to sunlight; and it is conceivable that the doubling of the daily period of sunlight exposure might be attended by a corresponding increase in the intensity and rapidity of chemical change in the body, and of the vital action correlated to it. In other words, continued exposure to so potent a chemical agent might be expected, in homely phrase, to "force the pace" of living, and thus tend to the premature exhaustion of life. As far as I am aware, no complaints tending in this direction have been made by any of the various compositors and others who now habitually work by electric light; but the time during which it has been in practical operation is hardly long enough for any satisfactory evidence to have been furnished on either side of the question. We must be content to say that we are at present unacquainted with the actual effects of prolonged exposure to the violet and ultra-violet rays, but we are hardly entitled to assume that these effects will be imperceptible. Unless they should hereafter be found to be decidedly injurious, there can be very little doubt, when we review the progress made during the last three or four years, that the electric light will ultimately be rendered available for most domestic uses; and, whenever this time comes, it will be likely to supersede other illuminants in the places where it is to be

obtained. As a matter of probability, it is likely always to be expensive in its applications to single small buildings, but there seems no reason why the necessary force should not be laid on from central stations to the houses of a street, or why this should not be accomplished at a moderate cost. Perhaps the best possible evidence of the prospects of the light, whenever these conditions can be fulfilled, was that furnished by the reduced price of gas shares at the time when it was announced that an invention of Mr. Edison's would fulfil the necessary conditions. The owners of gas property perceived at once that, in the presence of a really workable electric light, gas would fall into comparative disuse as an illuminating agent; and they were so strongly impressed with this belief that they were forgetful of the many other uses to which gas can profitably be applied; not the least of them being that of a motor for the production of electricity.

If we turn now from general principles to the consideration of detail, we shall find that the employment of the electrie light involves two widely different questions, namely, the supply of the electricity itself, and the lamps from which the light is to be obtained.

Electricity, as is generally known, is one of the most widely diffused of the forms of force, and is so correlated with motion, light, heat, chemical affinity, and magnetism, that any of these may be converted into it by proper appliances. It was first obtained in a demonstrable form by means of friction, or arrested motion; and afterwards, very largely, by means of batteries, in which certain chemical changes with which its development is associated were carried on. Such batteries, however, present several ineonveniences, even in their most approved forms; and the electricity of the present day, for many of its larger uses, is mostly derived from the so-called dynamo machine, which consist essentially of a revolving spindle, carrying coils of insulated wire, so wound upon it that they can be caused to move with great velocity through the lines of force of a powerful magnetic field. The mechanical arrangements for the production of this general effect have been numerous; but a French workman, named Gramme, devised the particular machine which is called after his name, and which was the first to yield an abundant and powerful eurrent of electricity at small expense. The Siemens machine, the Burgin machine, and the Brush machine, all differ from that of Gramme in points of detail, but not in principle; and it would be foreign to the purpose of this treatise to enter into the several peculiarities of their construction. We may say, for general purposes, that they all supply efficient electric currents; and these currents are to be considered in reference to two points, quantity, and tension or pressure. The former speaks for itself; the latter refers to the degree of force by which the current is driven forth from the machine which furnishes it.

Comparing electricity with gas or water, which flow through tubes, it differs from them in requiring some material substratum in which to move; and, just as certain substances will permit the passage of light, while others arrest it, so some substances are good and others are bad "conductors" of electricity, and some are absolute non-conductors. For its conveyance, therefore, instead of a pipe, we require a solid "conductor;" and this should be composed of a material which conducts freely, or which, in other words, opposes but small resistance to the passage of the current. Copper and metals are such materials, and copper wire is the conductor most commonly employed; but, when a small current has to be conveyed through wire of comparatively small diameter, platinum is used instead.

However good the conductor, it opposes some resistance; and hence there is a limit to the quantity of the current which it can convey. If the quantity supplied is too great, its motion in the conductor is impeded, and the latter becomes heated. When conductors are in contact with other conducting substances, as with the earth, they would lose their electricity; and hence it is necessary that they should be "insulated," or enveloped in some non-conducting material as a protective covering. The greater the pressure of the electricity, the greater will be the tendency to leakage; and the more complete, therefore, must be the insulating covering.

The materials most commonly employed as insulators are the gums, such as gutta-percha and india-rubber, either singly or in combination.

If the electric "installation," to use the accepted word, of any establishment be complete within itself, it will include a dynamo machine in some convenient situation, and conductors proceeding from this to the several burners. Where the establishment contains a steam-engine for other purposes, this will probably be used to drive the electric machine. In country houses, water-power may frequently be utilised for the same purpose. In other circumstances, a gas-engine may prove to be the most economical motor; but, at present, the expense of any separate installation, unless in cases where an otherwise absolutely wasted steam-power could be applied, would be much in excess of the cost of gas. Electric light so produced can only be regarded as an expensive luxury, adapted for wealthy people who choose to pay a certain price; but its economical use cannot be realised until the necessary motor power is supplied by central machines of great magnitude, supplying the wants of a considerable population. Several of the witnesses recently examined before the Select Committee of the House of Commons spoke of a population of 50,000 as being the smallest to which a system of electric lighting could be applied as a fair trial of its costliness or economy as compared with other illuminants; and all agreed that, although the success of electric lighting was beyond doubt as a laboratory experiment, it must be attempted on some such scale as the above before many doubts with regard to it can be finally decided. A perfect installation would require to be supplied with electricity by a number of steam-driven machines, the total of them being rather in excess of the actual requirements, so that the temporary failure of any one machine might not condemn any part of the district to a corresponding period of darkness. The conductors, in such a case, would start from the machines as solid rods of copper, and would be continually reduced in bulk by throwing off branches like those of a tree; the ultimate ramifications of which would be led into the individual houses to be supplied.

By the recent Act of Parliament, the strict functions of the light companies will be limited to this supply of electricity; and each householder will be at liberty to use any burners that he pleases, subject only to the condition that they must not be of a kind to interfere with the due supply of electricity to others. The conductors leading into individual houses will be furnished with meters, to declare the amount of electricity which has been consumed; and these meters, which are still somewhat in their infancy, are based upon a determination of the amount of chemical change effected by the current. Moreover, for the security of the householder, a short length of lead will be introduced into the main conductor entering the house, this lead having a carrying capacity sufficient for the largest current which the lights in that house can require. If, by any mischance, the amount of electricity supplied should be in-

excess of the requirement, so as to produce risk of accident from heating of the conductor, the piece of lead would be fused and fall, thus interrupting the circuit and cutting off the supply. It is probable enough, while the art of lighting up large districts is still rudimentary, that many of such fusions may occur; and hence it will be the part of prudent persons, until a system of electric lighting has been thoroughly tested by experience, not to leave themselves entirely dependent upon its success. Gas or lamps should be kept in reserve, and should be available against any accidents that may occur.

Such being the state of things as regards the current, we come next to the lamps; and, in this place, the arc lights may be briefly dismissed, as generally unsuitable for domestic purposes. For large open spaces, streets, railway stations, and the like, they answer admirably, but not for ordinary domestic interiors. They may be employed in large workrooms; and, as far as I can ascertain, the "Rapieff" lamp seems the best for this purpose. It is subject to the disadvantage that its carbons are not kept together by any self-acting contrivance, but require to be adjusted by hand about once in half an hour; but its light is of good quality, and, what is still more important, is singularly uniform and steady.

The only other kind of arc requiring to be noticed for interiors is the newly-introduced "Sun" lamp, for the supply of which a company has lately been launched with some parade. It consists of a small block of sandstone, through which are cut two channels, semicircular in outline, their flat sides turned towards each other, and inclining towards each other from above downwards, so that they are nearer together below than above. At the bottom of the sandstone block placed a slab of white is marble, flat above, where it is in contact with the sandstone, and in which a central cup, about an inch in diameter, is scooped out below. Two perforations in the marble, large enough to permit the passage of a piece of stout wire, connect the interior of the cup with the channels in the sandstone above. These channels are occupied by two rods of carbon, semi-cylindrical in shape, which move freely in them, so that they would fall through if the channels were not closed at the bottom by the piece of marble. The several parts of the apparatus are held together by a metal framework, and, in order to prepare the lamp for lighting, the carbons are united by a piece of wire which crosses the cup and passes through the perforations. The other ends of the carbons are connected to the conductors. When the current passes, the wire, which is too small to carry it, speedily becomes heated, fuses, and falls, and the gap thus established is crossed by the electric arc, the current passing through the perforations in the marble, and across the inside of the cup. As the carbons are wasted, they sink in their channels by the action of gravity, and require no interference until one of them is consumed. The arc not only affords light itself, but it soon raises the marble to a white heat and renders it luminous; so that the effect is something like that of the Drummond light, and a profuse flood of illumination is cast down below. The disadvantages of the lamp are that it gives out much heat, and that the light, issuing mainly from within the cup, descends in a beam of conical shape, which extends only over a circle the size of the base of the cone. The higher the lamp the larger will be the circle of illumination; and, as the whole contrivance is small and light, it can be run over a pulley nearly to the ceiling, and lowered to be prepared for re-lighting. Still, there are few rooms sufficiently high to render the luminous circle nearly co-extensive

with their floor space; and the contrast between the parts within this circle and the parts external to it is such as to render the latter unpleasantly dark by comparison. In an atmosphere containing oxygen, the marble is, of course, consumed and driven away; and the block has to be replaced daily, or at short intervals, according to the number of hours during which the lamp is burning.

For domestic uses, however, the contrivances most generally applicable are the various incandescent lamps, containing carbon filaments in sealed globes; and it might be thought, by any who saw one of these in successful operation, that the problem of electric house-lighting had been entirely solved, and that nothing remained but to apply the solution in practice. Such an impression would be erroneous, for it is doubtful whether any of the incandescent lamps now in existence will satisfy the requirements of consumers, or will hold their ground as permanent contrivances. When a carbon filament is heated to whiteness by its resistance to an electric current, it is, if in an atmosphere containing oxygen, immediately converted into carbonic acid and carbonic oxide, and so destroyed; and it was hoped that by heating it in a vacuum it would remain unchanged, so that it would convey the current, and display the light, for a long period of time. This expectation has not been fulfilled; partly, it is supposed, on account of the impossibility of obtaining a carbon filament of a perfectly homogeneous character. When one portion of the carbon differs in density, or in the arrangement of its particles, from another portion, the tendency of the current is to shake asunder the constituent molecules, so that the filament becomes disintegrated and broken. Most makers profess that the natural life of an incandescent lamp should extend to a thousand hours; but many lamps fail within one hour, and in many others, if they are examined after a short period of use, the globe will be found lined with a delicate film of carbon particles, showing that a process of disintegration is going on. Some makers fill their globes with a gas that is not a supporter of combustion, and nitrogen has been used for this purpose, but the experiments with it have not been altogether successful, and it is said that the carbon is broken up by the gas itself, being pelted to pieces by the impact of its molecules. Other gases have been used in the same manner, some, it is said, with advantage; and the Swan lamps are filled with a gas the nature of which is not made known In this and in many other details manufacturers are naturally reticent about points of construction from which they hope to derive advantages over their competitors.

The filaments of carbon are prepared and arranged differently by different makers, and with regard to them also there is an unwillingness to impart complete information. Mr. Edison's filament was originally, and probably still is, a strip of charred card, in the shape of an elongated horseshoe, while in some other lamps the filaments appear to consist of charred string. In the preparation of either string or card for combustion, and in the manner of carbonising, there are no doubt trade secrets; but it cannot be said that any of these secrets have as yet conducted their possessors to uniform or assured success. So far is this from being the case that the Edison lamp is safeguarded in use by being worked with only a comparatively feeble current, which does not raise the carbon to full white heat, and which therefore diminishes the stress which would otherwise be thrown upon it. The effect of this precaution, however, is to diminish the light, and also to impair

its quality. Being furnished by a comparatively feeble incandescence—one which is red rather than white—it is deficient in the violet rays which it is a special advantage of the electric light to supply. As may be seen any evening, the light furnished by the Edison lamps on the Holborn Viaduct is inferior to that of the Siemens gas lamps in the adjoining street; while, speaking generally, it may be said that the light given by incandescent lamps is not more than one-eighth, or at most one-seventh, of that given by an electric arc driven by the same horse-power.

The general appearance of an incandescent electric lamp is now very familiar. It consists of a thin globe of transparent glass, more or less oval in shape, about as large as a medium-sized lemon, and with a stem by which it can be attached to the apparatus by which it is supported. Within the globe there is a filament of carbon, sometimes flat, sometimes round, varying in shape in the lamps of different makers. This filament is connected at each extremity to a fine wire of platinum, which passes through some kind of insulating material in the stem, is united to the carbon in a variety of ways, and constitutes the means of connecting it electrically with the copper conductors external to the lamp. In many situations, as when placed at some height in large rooms, incandescent lamps may be left exposed; but when near the level of the eyes they should be within globes of opal glass; and, when placed on standards for table use, the upper portions of these globes should be covered by opaque screens, to cast the light downwards, and to cut it off from direct impact upon the eyes.

In the Edison lamp, the carbon filament is a flat band, in the shape of an elongated horse-shoe, and I have not been able to ascertain the nature of the joint by which it is connected to the platinum. The lamp is said to give the light of sixteen candles, when driven by a current which it can bear without disruption.

In the Lane-Fox lamp the carbon is in the form of a round thread, and has the shape of a capital U turned upside down. The extremities are connected with the platinum wires by a joint formed by Indian ink and metallic mercury.

In the Swan lamp the carbon filament is round, and is said to be connected with the platinum without any intermediation, by means of a so-called "weld." The filament describes a circle at its summit, as if it had been caused to make one twist round a stem half an inch in diameter. The platinum wires terminate in rings or loops, into which the extremities of the copper conductors are hooked; and, in order to keep the junction taut, so as to maintain metallic contact, the globe is supported on a coiled spring, which pushes it away from the stem from which the hooked extremities of the copper wires project. This coiled spring is sometimes thrown into vibration by external movements, and the light may in that case be interfered with. The ordinary illumination is about sixteen candles.

In the Maxim lamp the carbon is longer than in others, and is bent down in the middle, so that it resembles a capital U in the natural position, with each arm of the letter turned again down on the outside to form connection with the platinum. This is done by a tiny rivet. The lamp requires twice as much electricity as those already mentioned, and gives approximately twice the light, or about thirty candles.

In the Nothomb lamp the carbon has the shape of an inverted U, and is more

massive than in those already mentioned. It is united to the platinum by a sort of splice, secured by a twist of fine copper wire. This lamp is of Belgian invention, and is said to be twice as durable as others, the average life claimed for it being two thousand hours. I am not aware that it has as yet been sufficiently tested in this country.

From the point of view of the consumer, and for household purposes, it may fairly be said that the supply of electricity is a matter which must be settled by competition between different systems, so that the least costly may survive. The light will not be available for general purposes until the electricity can be supplied on a large scale, by companies or public authorities; for the cost of single installations must always be practically prohibitive in any but very large establishments. Those who are best qualified to judge, and who are not concerned in putting the matter in a rose-coloured aspect, admit that the question of cost cannot yet be determined; and, while they hope and believe that the eventual supply of electricity will be at a price comparable with that of gas, they hesitate to commit themselves to anything much more definite. There will be difficulties about insulation and leakage, but these will not affect the consumer farther than by increasing the general cost of the supply. Leakage within houses is not to be feared; for the quantity and pressure will be regulated by the fusible portion of the conductor to each house, and no danger from this cause ought to be permitted to occur. There is also reason to hope that a domestic supply of electricity may hereafter be maintained by portable accumulators, capable of being delivered ready charged from the works, and replaced when they are exhausted, but this expectation has not yet been practically realised. The accumulators now made consist chiefly of lead; and, although they may be made to work very well for many purposes, yet their great weight is prohibitory of their general economical employment.

Whenever electricity is laid on to our houses, and it may be conceded that, in all probability, the time when this will be done is not far distant, the consumer will find many lamps offered to him for its consumption. From what has been said already, it is plain that none of those now existing can be regarded as entirely satisfactory; but they will in all likelihood be improved or superseded before the time for any large demand for them can arrive. At present, therefore, many elements of the matter are still in an experimental stage; and, although the electric light affords many advantages when one can get it, the time for its universal application, or for its coming into serious competition with oil or gas, is probably more distant than many sanguine projectors have led the public to believe.

CHAPTER XLI.

GAS AND GAS-LIGHTING.

Early Introduction of Gas-lighting—Its first Defects—Mode of Measuring Gas and other Light—Unfair Procedure of the Companies—Coke, and not Gas, their Primary Object—Evils and Inconveniences of Gas—Leakages—Turning off the Main not advisable.

When we dismiss electricity, the remaining sources of artificial light are gas, distilled either from coal or from oil, together with the mineral oils which may almost be described as natural gas in a fluid form, and the other solid and liquid fats which are employed either to make candles, or to be burnt in lamps. Besides the difference in form between gas and other fuels, which allows gas to be driven into the burners by pressure alone, independently of the capillary attraction of a wick, the two series of illuminants differ also in this, that gas and mineral oils, except for accidental impurity, are composed only of hydrogen and carbon, while all animal and vegetable fats contain a certain proportion of oxygen in addition to those elements.

In the form of light carburetted hydrogen, combustible gas has long been known as an exhalation from the earth, seen usually in the neighbourhood of stagnant water; and such exhalations were traced to adjacent coal beds, by Shirley, in the year 1659. There are several places where, by the insertion of a tube into some natural fissure or artificial boring, the issuing gas may be inflamed; and the light thus procured is exhibited as one of the sights in the neighbourhood of the Falls of Niagara. Such carburetted hydrogen, however, does not usually contain carbon enough to be of value for illuminating purposes; and its flame, although brighter than that of pure hydrogen, is still only faintly luminous. Illuminating gas continued to be a matter of interest to scientific chemists, but did not attain any practical value until the year 1792, when Mr. William Murdoch, of Redruth, lighted his own house by gas distilled from coal, and conveyed in metal pipes over a distance of 70 feet. His gas laboured under the disadvantage of evolving exceedingly noxious products from the impurities which it contained; insomuch that it could only be burned in connection with flues or similar arrangements, by which the whole of the products of combustion were conveyed into the chimneys or otherwise removed from dwellings; and it was not until the method of purification by lime was introduced by Dr. Henry and Mr. Clegg that the presence of naked flames could be tolerated.

In England, the chief pioneers of gas lighting were Messrs. Boulton and Watt, who caused part of their manufactory at Soho, near Birmingham, to be lighted with it in 1798, and who gave a public exhibition of the light in 1802, on the occasion of the general illumination in consequence of the peace of Amiens. In 1808 Mr. Murdoch communicated the results of his experience in gas lighting to the Royal Society; the new illuminant having already been used in the Lyceum Theatre, where it was introduced in 1803, and on one side of Pall Mall. After this, mainly in consequence of the great exertions of Mr. Winsor, it came rapidly into general use; and, in 1815, it was introduced into Paris.

The illuminating power of gas, in accordance with the principles already laid down, depends upon the incandescence of its carbon element, which incandescence is produced by the heat yielded by the combustion of its hydrogen element; and it follows that these two elements must bear a certain proportion to one another, and also to the oxygen available for the purpose of consuming them, in order that the best results may be obtained. The hydrogen must be present in sufficient quantity to produce the necessary heat, and the earbon in sufficient quantity to afford the required illumination; while, if there be any lack of oxygen, either in the general atmosphere surrounding the flame or in the portion which can obtain access to it by reason of the arrangements of the burner, part of the carbon will escape oxidation after it has been heated, and will be given off in the form of black smoke or soot. In order to obtain good light, therefore, we must have a suitable combination of hydrogen and carbon in the fuel, a sufficiently oxygenated atmosphere in the room or other place where combustion is carried on, and a sufficient freedom of access of this atmosphere to all parts of the flame. At the same time, the access of atmospheric air must not be too free, or the flame will be cooled to such an extent that a proper incandescence of the carbon particles will no longer occur. This effect may be seen, from time to time, in the case of any gas flame that is exposed on a windy night; and is constantly observable in the case of street illuminations.

The permanently gaseous hydro-carbons are two in number, the light carburetted hydrogen, or marsh gas, already noticed, which consists of one element of carbon and four of hydrogen, and the heavy carburetted hydrogen, olefiant gas, or ethylene which consists of two elements of carbon and four of hydrogen. The latter, therefore, contains twice as much carbon as the former, and constitutes the most important element in illuminating gas. Besides these two, coal gas eontains other hydro-carbons still richer in the carbon element, of which naphthaline, containing five elements of carbon to four of hydrogen, may be taken as the type. These heavier hydro-carbons, however, although they possess great illuminating power, are only gaseous at high temperatures, and are liable to be deposited in solid or liquid forms in the pipes. Many contrivances have been employed by different inventors, to some of which it will be necessary to refer hereafter, in order to enrich gas by supplying it with the heavier hydro-carbons in such a manner that their deposition may be avoided.

The accepted method of measuring the illuminating power of gas, or, indeed, of all other illuminants, is by comparison with the light afforded by a candle of a stated composition burning at a specified rate. The standard adopted under the sanetion of Acts of Parliament is a spermaceti candle, burning at the rate of 120 grains of spermaceti an hour; and the intensity of a gas flame, burning in a given time a known quantity of gas, is expressed as being equal to so many candles. The method in which this determination is effected will require a brief digression.

The art of light-measuring depends mainly upon a comparison of the blackness of the shadows cast by the same object when illuminated by different flames. The diagram in Fig. 186, taken from Mayer and Barnard, will exhibit the rationale of the process. It represents a screen of white paper, supported in a vertical position, with a small wooden rod upright before it, a candle, and a lamp. These two being somewhat apart, each will cast a separate shadow of the rod upon the paper, and the lights should be so moved as to bring the adjacent edges of the two shadows

into close approximation. One of them will then be seen to be darker than the other; but, by placing the light which casts the darker shadow farther from the rod than the other, the two may be equalised. In the case supposed, the shadows are supposed to be equal when the candle is 22 and the lamp 44 inches from the screen; and, as we have seen that the intensity of light diminishes as the square of the distance, a correct comparison between the two lights will be made by dividing the square of one by that of the other. The square of 22 is 484, and the square of 44 is 1,938, in which 484 is contained four times. We say therefore, that the flame of the lamp is four times as bright as that of the candle, or that the lamp gives four-candle light.

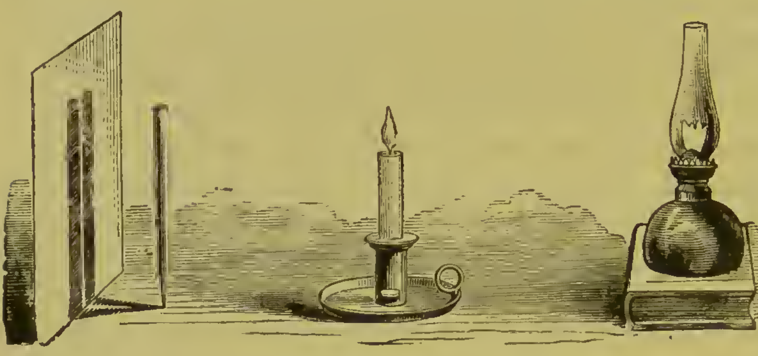


Fig. 186.—Measuring Illumination.

An application of the same principle, better adapted for accurate work, is furnished by the photometer of Bunsen, in which the standard light and the light to be tested are placed at the extremities of a graduated horizontal bar, on which slides to and fro an upright rod, carrying a piece of paper on which a central disc has been rendered translucent by wax or oil. A metal screen is so placed that the right eye sees the right hand side of the paper, which is turned towards one of the lights, and the left eye sees the left hand side, which is turned towards the other light; and the paper is moved to and fro until the central illumination, which for each eye is reflected from one side and transmitted from the other, appears absolutely equal upon the two sides of the paper. When this condition is fulfilled the relative intensities of the lights are read off on the graduations of the bar, according to the squares of their relative distances from the sheet of paper. In a photometer invented by Mr. Methven, the "standard candle" is replaced by so much of the flame of an argand burner as will pass through a slit of known dimensions; and, as the actual candles are very variable, this new photometer is rapidly gaining ground among practical men.

In estimating the illuminating power of gas it is usual to reduce the actual gas consumption, by calculation, to five cubic feet per hour; and hence, when we say that a given gas is equal to so many candles, it is implied that the equality is for that amount of consumption. This applies equally whether we are testing the gas itself, in a known burner, or testing a burner with gas of known quality.

In this country, the supply of gas is chiefly in the hands of great joint-stock companies, who, not content to sell an useful commodity as other commodities are sold by other manufacturers, havo succeeded in obtaining from Parliament a variety of powers and privileges which are unnecessary for the conduct of their business, and which, in most cases, are prejudicial to tho interests of their customers. As some compensation to the latter, Parliament has enacted that the gas supplied should be of a certain illuminating power—in the metropolis sixteen candles

—and a common practice of the companies is to make the bulk very inferior to this standard, and to bring it barely up to measure by the addition, to each batch, of a sufficient quantity of gas of a better quality, made from cannel or other well-adapted coal. The bulk of the gas made in London is from coal which yields bad gas but good coke; and the companies habitually sacrifice the interests of the light consumer, whom they control by their monopoly, to those of the coke consumer, who is free to buy what he wants in the open market. The practical result is that the purchaser of gas, of which the companies are professedly purveyors, is made to suffer for the benefit of the purchaser of coke, which, *quâ* gas manufacture, should be regarded as a waste product, proper, indeed, to be put to the best and most profitable use, but not to be made the primary object of the manufacturers; who, by thus reversing the natural relations of their products, may almost be said to obtain their monopolies and privileges under false pretences.

When gas was first introduced as an illuminant, the art of lighting was in a very backward condition; and the abundant supplies of cheap oil which are now attainable were not to be procured. The new agent offered immense advantages over all others which could be brought into competition with it; and its triumph was speedy and complete. Since then, the methods of making and of distributing gas have not been improved in any very material points: while the art of lighting by oil has been not so much revolutionised as created. The two kinds of fuel stand, to-day, in totally different relative positions from those which they occupied at the beginning of the century; and gas, notwithstanding its enormous consumption in manufactories, shops, churches, and public buildings of every description, is beginning to fall into some disrepute for the interior illumination of dwellings. On account of obvious considerations of economy, cleanliness, and convenience, it is perhaps to be preferred for lighting passages and staircases; but for rooms which are constantly inhabited it offers many compensating disadvantages. As commonly prepared, sold, and consumed, it loads the air with noxious vapours, which are injurious to books, pictures, and furniture, and which cannot be innocuous to the human lungs; it produces heat out of all proportion to its light; it dries the atmosphere of a room to such a degree as often to render the dried air irritating to the surfaces of the eyes; the pipes or meters are liable, at critical times, to fall out of order in some respect which requires a gas-fitter to repair; and the accidental leakages are not only foul-smelling, but are also attended by liability to cause dangerous and destructive explosions. Moreover, it is often exceedingly difficult to trace them to the place from which they proceed.

It will seem to many readers that the foregoing is too heavy an indictment against a mode of lighting the convenience of which is universally appreciated; but a small amount of reflection will suffice to show that every count can be sustained by ample evidence. Taking them in their order, and referring first to the products of combustion, it is probably true that, if gas were prepared with adequate skill, from coal of the kind best suited to the purpose, and with a view to the interests of the consumer, it would be entirely harmless. Unfortunately, the reverse of this picture is ordinarily the true one. There is skill in abundance, but the object to which it is directed is to supply the cheapest, and consequently the worst, gas which can be made to pass muster, and to keep the companies clear of the penalties prescribed by their Acts. The selection of the coal, the limits of the purification,

and the ultimate dosage with better gas to raise the illuminating power to the legal standard, all have this aim in view. One of the consequent results is to supply impurities which lead to the formation of sulphuric acid during the process of combustion, and this exercises an injurious influence upon books, paintings, woven fabrics, metallic surfaces, and many other things. A few years ago, it was found that the backs of the books in one of the principal London clubs had been so seriously damaged by this cause that the use of gas was immediately discontinued in the library; and such an experience is by no means an isolated one. Evidence of the impurities ordinarily contained in London gas may be obtained at any time, by simple inspection of the deposits left upon the interior of the chimney glasses of burners, or upon the glass or other shades which are suspended over the flames for the protection of ceilings. I am not aware of any experiments by which the facts have been accurately determined, but I am under the impression that gas consumes more oxygen, light for light, than any other description of fuel; and that in this way also it contributes to the deterioration of the air; while ample proof of its heating properties may be obtained, in any room in which it has been burning for half an hour, by the simple process of ascending a pair of steps, so as to bring the head to a level above that of the flames. When a gas burner is suspended from the ceiling, with its flames above the heads of the occupants of the room, the effect of this superheating of the upper portions is exceedingly mischievous. It presents an effectual barrier to the ascent of the air which has been vitiated and warmed by respiration, but which is still heavier that the gas-heated air above it; and thus, for all purposes of ventilation, it practically brings down the ceiling to the level of the gas flames, and reduces the cubic space of the room accordingly. Such a result may, no doubt, in great measure be obviated by good arrangements for ventilation; but good arrangements for ventilation are sufficiently rare to deserve very careful observation when they can be found.

The drying of the air by gas is another inconvenience which ventilation might obviate, but which is none the less a real evil. Wood engravers, and those engaged in other occupations which require a strong light near the eyes, are accustomed to protect themselves by placing near them on the table a large sponge well soaked with water, which is renewed from time to time, so as to provide a source of supply to make good the atmospheric moisture as fast as it is removed, and to prevent the effects of very dry air, which is irritating always to the eye-surfaces and often to the lungs. It is hardly necessary to observe that the effects of this, and of all other inconveniences incidental to the actual combustion of gas, are increased in proportion to the number of persons who occupy a given cubic space within which the flames are enclosed.

The foregoing observations are intended to apply, in great measure, to London; and, although they are no doubt more or less true of other places also, there are many places the inhabitants of which are better treated by their gas purveyors. Such better treatment may depend upon the gasworks being in the hands of some municipal or other public authority, which has no purpose to serve other than the advantage of the consumer, or, in some cases perhaps, upon the character of a coal supply which is easily accessible in the particular locality. The city of Cork, for example, has long enjoyed gas of peculiar excellence, and that of Edinburgh, as every one who has been there must be aware, is far superior to that of London.

The inconveniences attendant upon accidental derangement of machinery, either at the works, in the public mains, or in private houses, are liable to occur wherever gas is used, and these are sometimes exceedingly great. They are such as to render it a matter of common prudence for no householder to be entirely dependent upon gas for his illumination, but always to reserve the power of supplying its place by lamps or candles in case of need. There is a tradition that when Sir Walter Scott, on his removal from Ashestiel to Abbotsford, gave a great house-warming at the latter residence, all the gas-lights suddenly went out in the middle of the festivities, and left the assembled guests in utter darkness. Sir Walter, wishing to be in the van of improvement, had caused Abbotsford to be lighted entirely by gas, from attic to basement, and had cast away lamps and candles as remnants of barbarism. The effect was that no substitute for the defaulting gas could be procured, until a messenger had been dispatched to Melrose to clear the village shops of such dip candles as they might contain; and that ultimately, but not until after the lapse of a considerable time, some of these unsavoury illuminants were brought, were fixed to the walls in extemporised sconces, and the dancing was continued with as much spirit as could be expected in the circumstances. A person whose house is entirely lighted by gas is at the mercy of strikes among the workmen, of explosions in or accidents to the local main, and of imperfections within his own walls; and it usually happens that something wrong with the gas is not discovered until the time for lighting it, when skilled workmen, if the defect chances to be at home, are not to be procured until the morrow. It is in accordance with the usual march of events that gas, if it goes out when it is wanted, always goes out at the most inconvenient time; and it is therefore never desirable to allow the comfort, or the pleasure, or the work, of an evening to be dependent upon the integrity of this one string to the bow.

A not uncommon source of difficulty with gas in private houses, especially in those which are supplied by small gasworks, arises from the deposition of water in the pipes. Gas is stored over water, and a large number of meters containing water are still in use. Gas has a considerable power of absorbing the water with which it is in contact, and readily deposits it again if brought to a somewhat lower temperature. If such deposit occurs in the pipes in the interior of a house, the moisture will gradually trickle down to the lowest point of the system, and will there accumulate until it forms an impediment to the passage of the gas, which will at first get through in a stream of bubbles instead of by a continuous flow, and will supply the flames in such a manner that they rise and fall as if with a sort of pulsation, producing a flickering which is very unpleasant, and which renders the flame almost useless as a source of illumination. In the metropolis, where the enormous and rapid consumption calls for daily manufacture, the gas does not rest long enough in the reservoirs to absorb much water, and the general employment of dry meters prevents the absorption which might otherwise occur in the houses of consumers; but, in the gasworks of country towns, where daily manufacture is not practised, and the gas is stored for two or more days at the works, the absorption is very apt to occur. Consumers who are dependent upon such a source of supply, or who use wet meters, should have a small pipe introduced at the lowest point of their domestic service, as an outlet by which any accumulation of water may be permitted to escape. The pipe may be very small, should be carried vertically downwards for

an inch or two, and fitted with an ordinary tap. When this has not been done, and where the accumulation of water displays itself by sudden flickering, the accumulation may be withdrawn, in the absence of a skilled workman, by first turning off the gas at the main, and then drilling a hole, with a bradawl or small gimlet, at the lowest part of the pipe. As soon as the few drops of water have escaped, the hole may be plugged by melted tallow from a candle, and the gas re-admitted and lighted. Of course, the tallow plug should be replaced next day by one of a more secure character. During frost, the accumulations of water are apt to be still more troublesome, because, on account of the crystalline formation of ice, and the consequent increase of the bulk of water in freezing, a drop or two which had collected in a pipe without perceptibly affecting the current may entirely obstruct the calibre when frozen. Whilst these lines were being written, in the winter of 1880–81, a single burner in my own house was actually rendered useless in this manner, the others not being affected. In such a case, of course, the possibility of melting the ice-plug would depend upon the accident of the position and course of the pipe. In Edinburgh, the state of things was still worse, for there the wet meters in general use were frozen almost universally, and large portions of the city were entirely deprived of gas in the houses, while the same thing happened at Blackheath and in other places near London.

The leakages of gas which occur in dwelling-houses may arise from various causes, and, on account of the offensive smell of gas, they usually declare themselves in time to secure the inhabitants against any danger from explosion, if only proper precautions are at once adopted. In this, however, as in so many other matters, the actual dangers arise as much from carelessness or ignorance as from the necessities of the position. When gas and atmospheric air are mixed in certain proportions, the atoms of oxygen are in close relation with those of hydrogen, and upon any elevation of temperature they rush together with such violence as to produce explosion, and very destructive consequences have been often produced in this way. The mixture of gas and air, being lighter than air itself, always ascends to the upper part of the room in which the escape occurs, and many domestic explosions have been occasioned by holding up a lighted candle for the purpose of ascertaining the place of leakage. On one occasion, when leaving the house of a patient, I called the attention of the owner to the smell of gas, and advised him to see about it forthwith. He took a light into the drawing-room, from whence the smell proceeded, and held it up to the top of the suspended gaselier, thinking to light the issuing stream, and thus to show the position of the leak. The result was that, just as the front door had closed behind me, the drawing-room window-frames followed me into the street, and on returning to the house I found that other serious mischief had been done. In all cases of leakage, before a light is brought, the gas should be turned off at the main, and then the doors and windows of the room in which the leakage occurs should be set wide open, so that the accumulated gas may be diluted and removed by a free current of air. When this has been done, the main may be re-opened, and then a light may be safely employed as a detective.

Perhaps the most common source of gas leakage is to be found in the defective character of the fittings and workmanship. A case lately came under my notice in which a house, newly furnished and decorated at considerable expense, was never free from a suspicion of the smell of gas. This was traced, after much trouble, to

the faulty construction of some expensive gaseliers, which permitted leakage to a small extent, sufficient to be offensive, but not sufficient to become a source of danger in rooms which were inhabited and to which air was freely admitted. The gaseliers had not been properly tested before they were fixed, and they had openings of extreme minuteness by which escape was permitted. In purchasing such fittings, it is prudent to require from the seller a warranty of their perfection in this respect; and he will then, for his own protection, be tolerably certain to obtain a similar warranty from the manufacturer, who, in his turn, will not send them out until a proper test has been applied to every part. The best for the purpose is to drive air into them under moderate pressure, while the fittings themselves are under water. Any escape, however small, will then declare itself by the ascent of bubbles. In the same way, a gasfitter should be called upon to warrant the soundness of the work done by his men, and he will then be likely to keep them under proper supervision.

It is the practice of some householders to turn off the gas at the main every night; a course by which every light then burning in the house is immediately extinguished. When this is done, it will sometimes happen that the special tap of some particular burner, which was lighted at the time, is forgotten and left open; so that, when the main is again opened for the requirements of the next evening, this burner, if not at once either lighted or closed, will permit a free escape. Where the practice of turning off at the main obtains, too much care cannot be taken to see that every burner, whether known to be lighted or not, is visited and closed immediately afterwards; since otherwise, in the less frequented parts of the house, all the conditions necessary for an explosion will be prepared.

A curious illustration of the effects of total ignorance of gas and its properties came under my observation a short time since. A young lady, who had been brought up in a remote country house, came to stay in London, in a house which had a gasburner in every bedroom. It was the duty of the servants, each evening, to light the gas in the bedrooms, and to turn down each flame to a low point, so that anyone entering the room might turn it up without trouble. The guest, tired by her journey, went early to bed on the evening of her arrival, and, finding candles and matches on her dressing table, lighted the candles. Some time after, when the occupier was going to bed himself, his attention was called to a smell of gas, which, after some investigation, appeared to come from the guest's room. The lady of the house went to investigate the matter; and, on opening the door, found the smell overpowering. She opened the window and roused her guest, although not without difficulty. The young lady, when quite awake, professed her inability to understand how the escape could have occurred, "for," she said, "I was careful to blow the gas out before I got into bed." She did not understand the use of the stopcock.

In a house which I inhabited some years ago, an escape of gas was brought about in a very curious fashion. The smell made its appearance in my dining room, not in an overpowering, but yet in an unmistakable manner, and increased day by day. After all other methods of investigation had been tried in vain, the floor of the room was taken up; and then it was found that a gas-pipe had been so laid as to be exposed to friction from a bell-wire, which crossed underneath it at right angles to its course. The bell-wire had sawn a cut across the pipe, and at last had opened its calibre. Both the pipe and the wire had been laid down before the commence-

ment of my occupancy; and it was impossible to discover whether the bellhanger or the gasfitter had been most to blame in the matter.

The gaseliers or pendants used in sitting-rooms are commonly balanced by weights, and are made to slide up and down, so that the level of the illumination may be altered when required. In this arrangement, the lower sliding tube, into which the upper one is received, is double and contains water, by which the escape of gas is prevented. This water, from having only a very small surface exposed to the air, evaporates but slowly, but it does evaporate in time; and if the tube is suffered to become empty, gas must escape. If the tube is nearly empty, but yet contains sufficient water to seal the joint when the flames are high up, it will sometimes happen that by drawing them down the protection of the water is lost. Gas will then ascend from the mouth of the lower tube to the ceiling of the room; and may accumulate there to a dangerous amount before it is diffused downwards in sufficient quantity to give the alarm. Wherever such sliding gaseliers are used, it should be made a matter of routine to refill their tubes with water at reasonable intervals of time, say once in a month or six weeks. The refilling can be done by anybody, and requires only a pair of tall steps and a jug of water. If the gaselier is drawn down as far as it will come, and the lower tube is then filled up, the water will overflow and make a mess when the tube is pushed up again. It should either be only partially filled when drawn down, or, what is perhaps better, should be quite filled when it is pushed up as far as it will go. An excellent method of preventing evaporation is to fill the tube nearly to the top with water, and then to complete the filling with a little almond or olive oil. If this be done, the gaselier will require no further attention for an indefinite time.

It will be gathered from the foregoing that the prudent householder will prefer a dry to a wet meter for his gas; and that, even with the former, he will establish a depending opening by which the whole of the pipes within his house may be emptied of water in case of need; that he will take care to have such a warranty for the character of new fittings as may protect him against pecuniary loss in consequence of the supply of bad goods or bad work by his tradespeople; and that, in case of leakage betrayed by the sense of smell, he will carefully cut off the main supply, and secure thorough ventilation, before any light is suffered to be taken into the place from which the odour proceeds. Whether it is desirable to turn off the main supply at night, as a matter of habit, is, I think, very questionable. The pipe usually enters at some place not easy of access; and, if a light should be suddenly required in the night, in consequence of illness, or of other emergency, the complete exclusion of gas from the premises might entail some inconvenience. As regards the question of safety, I think I have never heard of either fire or explosion at night which were consequent upon the main pipe being left open; but I have heard of more than one explosion, and of many narrow escapes from explosions, which were occasioned in the way already described, by a tap having been left open in some room in which a light had been burning when the supply pipe was closed, so that free leakage was permitted when the supply pipe was re-opened. In my own house, where gas is only used in the kitchen, basement, entrance, on the staircase, and in a consulting-room where it is indispensable for professional purposes, I never have the main closed from one years' end to another; nor do I perceive in what way I should arrive at any additional safety by altering my practice in this respect.

CHAPTER XLII.

GAS PRESSURE, PIPES, AND BURNERS.

Three main forms of Burners—Influence of Gas Pressure—Variations in Pressure—Evils of Excessive Pressure—Governors—Description of the Principal Gas-burners.

Assuming that gas is to be burnt as a source of domestic light, the next question to be considered has reference to the manner in which this should be done. The burners in common use are three in number, the argand, the batwing, and the fishtail; with many modified forms of each.

The argand burner consists essentially of a small ring, usually about three-quarters of an inch in diameter, from the upper surface of which the gas escapes by a number of fine openings. The flame is therefore a hollow cylinder, and the air has free access both to its exterior and to its interior.

The batwing is a small tube, closed at the top by a hemispherical bulb, through which a vertical slit for the issue of the gas is cut by a fine saw. The flame is flat, and almost semicircular in outline.

The fishtail, or union-jet, is a tube with a flat circular top, in the centre of which is a central concavity or depression, in which two channels are bored in directions inclining towards one another from below upwards. The two issuing streams of gas meet, and each modifies the shape of the other, so that the flame spreads out into a thin sheet transverse to the direction of the perforations; and with sides which are at first semicircular, but which, as they ascend, become nearly parallel. The difference between the last two varieties is not of an important character, but they both differ from the argand in that the flame of this requires to be inclosed by a chimney, in order to secure the requisite regularity and steadiness of the air supply. The batwing and fishtail burners are often inclosed in globes, but they do not require chimneys, and the globes are to be regarded as ornaments or as adjuvants rather than as necessaries.

The pipes by which gas is distributed from the central reservoirs to the buildings in which it is consumed are manifestly of constantly diminishing calibre, the system bearing a rude resemblance to the trunk, boughs, branches, and twigs of a tree. The inner surfaces of the pipes of such a system oppose, as a matter of course, considerable frictional resistance to the passage of gas, which has to be driven along them by a certain amount of pressure, and this pressure must be increased when a larger supply is required, or when the gas has to be transmitted over long distances. Hence it is the custom of gas companies to keep the pipes full under a low pressure during the hours of slack consumption, and to increase this pressure during the hours of chief demand. It is also the practice to increase the pressure somewhat in anticipation of the demand, and to maintain it for a time after the chief demand has ceased; the result of which is that it falls in the terminal pipes at about the time when numerous jets which had previously been closed and inoperative are first lighted, and that it rises again suddenly when the majority of shop lights are being extinguished. Hence the pressure varies, not only

with the known amount which is applied at the reservoirs, and which can be reckoned upon, but also with the number of jets which may be lighted in the district at the time, an element which may be variable even on different days of the week. I have before me a diagram which gives a graphic representation of the variations of pressure near Charing Cross, on the 7th and 8th of February in the present year, the variations being recorded automatically on a revolving drum. The pressure is expressed in inches of a column of water; and at Charing Cross, during the quiet times of the day, as from one o'clock in the morning to three in the afternoon, it stood at about an inch and a half, or 1·5. At about a quarter past three, it rose to 1·8, falling almost immediately to 1·7, and, by four o'clock, to 1·6, no doubt in consequence of many lights having been kindled since the first increase of pressure at the works. At four, the central pressure was again increased, and the index steadily mounted until, by a quarter to five, it had reached 2·83. From this, as more lights were kindled, it fell in the course of twenty minutes to 2·3, and fluctuated between this and 2·5 until eight o'clock, when shops began to be closed, so that the pressure became excessive on the burners which were still in use, and rose to 3·25 by nine o'clock. From this point it declined gradually, reaching 2·5 by ten minutes before twelve, and falling abruptly to 1·5 in the course of the next hour. The pressure therefore ranged from an inch and a half to nearly three and a half between four and nine p.m., and fell again to one and a half between nine p.m. and one a.m.

In ordinary gas-burners, the supply to which is regulated only by a tap, these sudden and great variations of pressure are frequent sources of inconvenience and of waste. When the gas is lighted, probably before the evening increment of pressure commences at the works, the taps require to be almost fully opened in order to obtain a supply adequate for the maintenance of a flame of moderate size. As soon as increasing pressure drives more gas along the pipes, the previously quiet flames begin to flare and sing; and the rush of gas which issues from them no longer finds oxygen enough in the immediate vicinity of the flame to provide for its complete combustion, so that the room becomes filled with the vapour of unoxidised carbon, which is deposited in the form of fine soot, and which, to people of sensitive respiratory organs, produces an atmosphere of a very unpleasant character. Of course, in a room or other place which is occupied when the increased pressure comes into play, there is no further trouble that that of altering the tap of each burner until the flame resumes the desired character and magnitude; but in rooms which are for the time unoccupied, or in passages or on staircases, there may be much waste before attention is directed to the circumstance. An argand burner under excess of pressure gives off black smoke very freely; and I have more than once been absent from a room in which such a burner had been lighted under low pressure and left burning, and have returned to find a high, black, and smoky flame, and an atmosphere thickly charged with the fine black dust of unconsumed carbon.

In order to meet the inconveniences thus arising, various contrivances called "governors" have been invented. The object of a governor is to prevent the pressure in the pipes beyond where it is fixed from rising above a pre-arranged maximum, an effect which is produced by neutralising the pressure by some kind of interposed resistance. The earliest form of governor which I remember was a box filled with small shot, and so made part of the gas-pipe that the gas was com-

pelled to force its way between the pellets. Muslin filters and other contrivances have also been employed, and, in more recent times, governors have been made in such a manner that they are called into increased action by increased pressure, and are therefore self-regulating or automatic.

For the fluctuations of pressure which are due to alterations made at the central reservoir, or which depend upon the turning-off of many lights in the vicinity, a governor placed upon the main inlet tube of the house, just within the meter, would obviously be sufficient, and such an arrangement will often answer very well in small houses. In large establishments, however, there may be great fluctuations within the building itself, due to strictly local causes. For instance, the main supply remaining unchanged, the extinction of all the lights upon one floor of a large building may throw a much increased pressure upon the burners of the remaining floors. Internal changes such as this can only be met by the application of a governor to each burner.

The modern modifications of the three chief forms of gas-burner already enumerated have been chiefly due to the attention bestowed upon the question by Mr. Silber, Mr. Sugg, and Messrs. Bray.

It has long been known to natural philosophers that the attainment of perfect combustion requires a careful adjustment of the relative quantities of fuel and of atmospheric air; but Mr. Silber was, I believe, the first manufacturer who kept this requirement constantly before his mind as one which he would endeavour to fulfil. His earliest experiments had reference entirely to burners for oil, and it was only after having brought these to a very high degree of excellence that he conceived the idea of applying the same principles to burners for gas. He found by many careful trials that an excess of fuel over air produced imperfect combustion by lack of oxygen, while excess of air over fuel produced imperfect combustion by diminution of temperature; the ultimate result in both cases being a smaller amount of light than the quantity of fuel which was dissipated ought to furnish, and a liberation of compounds more or less noxious or unpleasant, and produced by the sub-oxidation of the unconsumed waste. In order to attain the best possible results, he constructed an argand burner for oil, in which the metal parts below the flame were of sufficient length to warm the air as it ascended through them, and in which the air admitted to the inner portion of the ring was made to pass through an opening of carefully calculated area, and then through and around a vertical tube, by which a portion of it was guided to the upper portion of the interior of the flame, where it arrived as a sort of reinforcement to that which had gained access from without, and which had already carried the combustion to a certain point. The results thus obtained will be more particularly described in speaking of oil burners, but they were sufficiently good to lead to the application of the same principles to gas, and thus, ultimately, to the details of the Silber-Argand burner, which is, according to Professor Wallace, the best which has been constructed.

The Silber-Argand is shown of full size in elevation in Fig. 187, and in section in Fig. 188. It is constructed of brass and steatite, and consists of tubes so arranged that two concentric currents of air have access to the inner surface of the gas flame, and two to the outer surface. The gas is admitted into a lower chamber of brass, and from thence passes into a cylindrical chamber of steatite, the roof of which is pierced by twenty-four holes, at which the gas escapes to feed the flame. The air

gains access to the interior of the flame through the square opening shown in the drawing, the size of which is carefully regulated, and passes from thence both within and outside of the vertical inner tube by which part of it is directed to the higher portions of the flame. It is by this graduation and division of the air-supply that the excellent results given by the burner are attained. It is commonly fitted with a governor, of a kind which requires adjustment as the pressure of the gas varies, but which provides for the maintenance of a uniform light and consumption, to whatever extent the variation may be carried. Quite recently, these burners

Fig. 187.—Silber Argand.

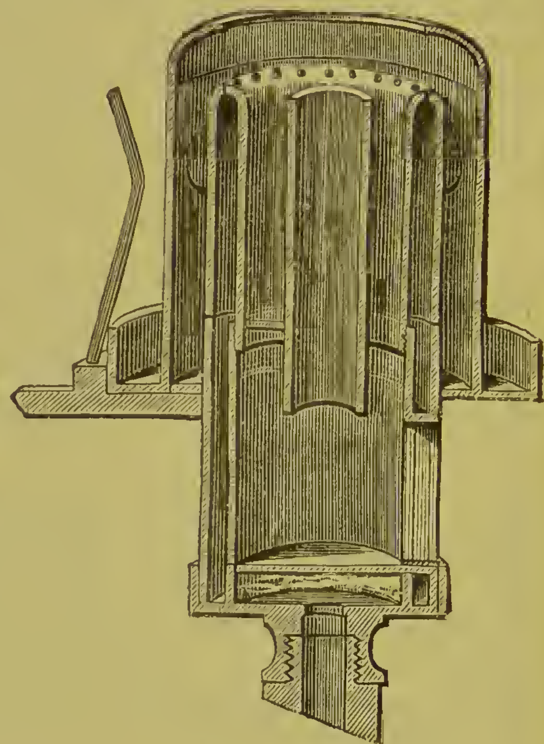


Fig. 188.—Section of ditto.

have also been fitted with automatic governors, calculated to pass either five, six, or seven cubic feet per hour, and they then present the appearance shown in Fig. 189. A Silber tubulated burner thus fitted requires a chimney of height adapted to its consumption, *i.e.*, 7-inch for five feet, 8-inch for six feet, and 10-inch for seven feet.

Mr. Sugg's argand burner, better known as the New "London" Argand, is readily distinguishable from others by the body of the burner being supported upon three fine tubes, through which the gas obtains access to the flame. This burner is shown in section in Fig. 190, and is thus described by the maker :—"At the point at which the gas enters is a brass nose-piece, A, screwed to fit the usual three-eight thread, intended by the manufacturers of all gas-fittings to receive the burner. This is drilled through its length, and slightly trumpeted at the top so as to fit the cone-shaped piece of metal projecting from the roof of the inlet chamber, B.

"The outside of the upper portion of the nose piece, A, is screwed to fit the inside of the inlet chamber, B, and thus, by an adjustment of this screw, by means of paper washers put on the shoulder at A B, it is possible to enlarge or decrease the

area of the passage through which the gas has to pass in order to supply three tubes, of which only two, C and D, are shown in the drawing, by which it is further conducted to the combustion chamber, E. This chamber is made of steatite, and is pierced by a number of holes, so arranged as regards size and number that the quantity of gas the burner is required to consume shall pass out at an inappreciable, or at the least possible, pressure, in order that the oxygen of the atmosphere—slowly ascending through the centre opening T, and the annulus formed by the edge of the air cone G, and the outside of the combustion chamber E—shall combine with the burning gas by natural

Fig. 189.—Silber Argand with Automatic Governor.

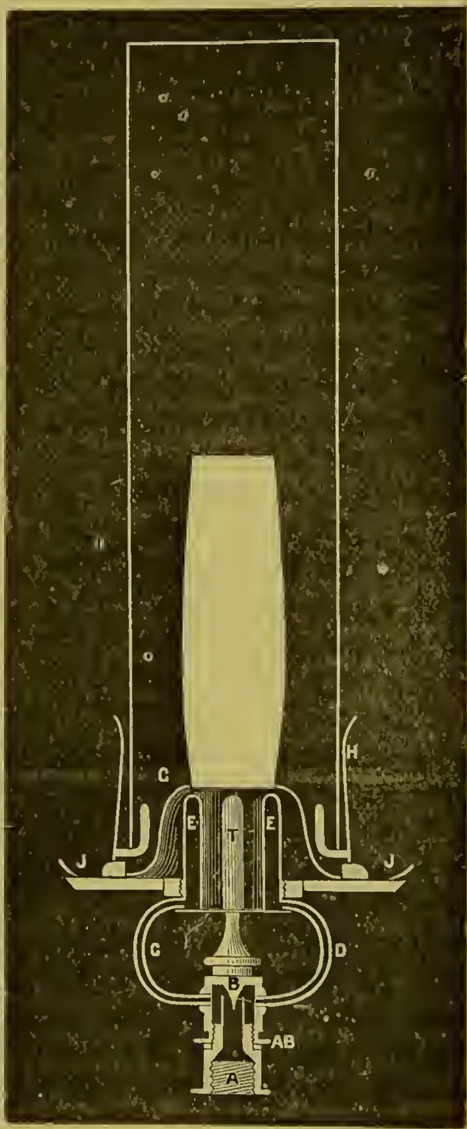


Fig. 190.—London Argand.

affinity only, leaving the nitrogen to pass freely out at the top of the flame. H is one of the three springs which are intended to keep the chimney glass steady in its place, and J J are two or three rests for a screen, globe, or moon, as may be desired."

This "London" argand differs from that of Mr. Silber in one or two unimportant features, and in two important ones, the first of the latter being that Mr. Sugg claims to obtain his results by so arranging the supply of gas to the combustion chamber that it shall issue at the least possible velocity, and at as low a temperature as possible. To accomplish these ends, he uses such a construction that the total area of gas inlet shall be less than the total area of

gas outlet, or perforation openings at the base of the flame, in the proportion of about one to six, and he makes his upper chamber of steatite, as in the Silber burner. The other important difference is that the Sugg burner has only one air channel within the flame.

Fig. 191.

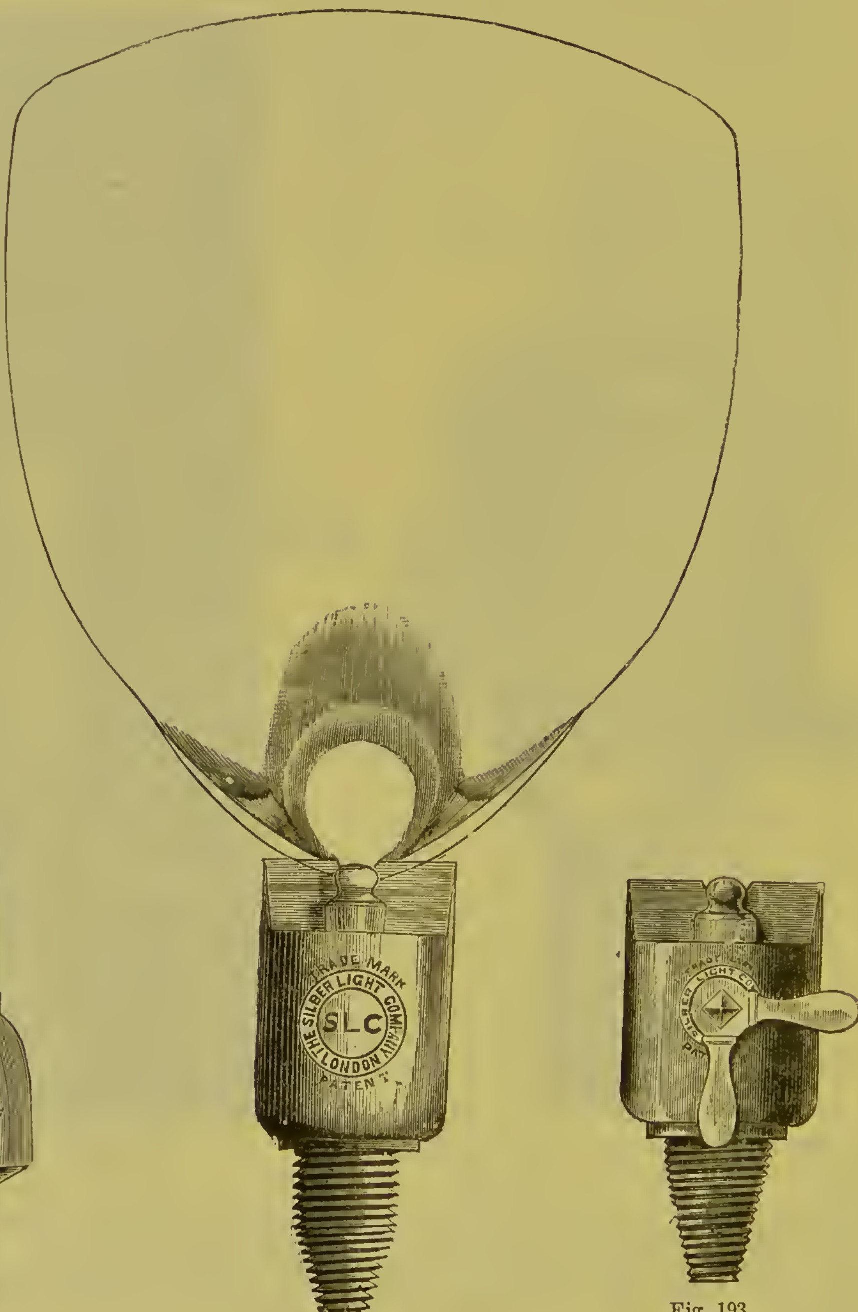


Fig. 192.

Fig. 193.

It is somewhat curious to observe that no claim is made by Mr. Sugg for the regulation of the air supply, and that no claim is made by Mr. Silber for the regulation of the gas supply. The two inventors appear to have been following distinct tracks of investigation. Mr. Silber has, however, arrived also at the point indicated by Mr. Sugg, having ascertained that in the Silber argand the gas issues at a very

low pressure or velocity, insomuch that the registration of the water-gauge never exceeds 0·10th of an inch, and is often scarcely above zero. In fact, almost every argand burner, when in actual working, must have its inlet area smaller than its outlet area. It would be impossible to use any argand without establishing such a condition by means of its tap, if not otherwise; and it will be found practically that the conditions insisted upon by Mr. Sugg would in this way be very nearly arrived at.

Considering the time and care which would be required for experiments for the purpose of arriving at any sound conclusion concerning the relative merits of different gas-burners, and the extent of the commercial interests which are involved, the task of pronouncing upon these merits is one which, to any single writer, would be at once difficult and invidious. I am therefore highly fortunate in being relieved from it by the reports which have been presented to the British Association for the Advancement of Science, in the years 1878 and 1880, by committees specially appointed for the purpose; but a detailed reference to these reports will be most conveniently postponed until after some description of the chief forms of flat-flame burners has been given.

In these also we meet Messrs. Silber and Sugg as the chief competitors.

The Silber batwing (Fig. 191) is essentially a combination of two common batwing slits, the lower of which feeds a little vase or chamber from which the upper one gives outlet. Hence the gas, escaping through the lower slit under pressure from the main, expands somewhat in the vase, and escapes from the upper slit into the flame at a diminished pressure.

The Silber "Concordia" burner is a modification of the fishtail or union jet; and its name seems intended to imply that the two elements by which the expanded flame are produced are combined more harmoniously and more perfectly than in any of the earlier forms. There have been several previous burners in which the union and reciprocal action of two jets of gas have been obtained by the combination of two distinct burners, placed at an angle to one another, instead of by the method which has lately been more common, of making two separate perforations in a single jet. In this way much more light has been obtained than could be given by the same two burners arranged independently; but in the new Silber "Concordia" burner the two small burners are combined in one nozzle, although separated by an intervening wedge-shaped piece of brass, and it is claimed that this arrangement yields results which surpass all previous ones. It is said that the illumination yielded by this burner is almost, if not quite, equal to that of the two best forms of argand. Fig. 192 shows the burner lighted, thus giving the size and shape of the flame; and Fig. 193 shows a recent modification, by the attachment of a small valve or lever, so fixed that by slight raising or lowering it shuts off the gas from one of the jets, leaving the other unaffected. By this means the consumption can be reduced when much light is not required, and a tendency to smoke, which is common in burners of this class when the flame is lowered, is obviated.

The Sugg batwing burner has recently been improved by an altered method of cutting the slit which gives issue to the gas; and which now, by means of a circular saw, is made to curve somewhat upwards at its extremities, so as favourably to modify the shape of the resulting flame. Another improvement is the addition of what Mr. Sugg calls a "table-top," a small horizontal plate of steatite immediately

below the slit, by which the flame is somewhat contracted, its shape modified, and its edges are rendered more luminous and more steady.

Many years ago, Mr. Scholl, of London, adopted the system of placing a small plate of platinum between the two orifices of the union jet, the result being that the initial velocity with which the gas escapes is spent by striking against the plate, and the gas ascends in a somewhat sluggish flame, which, in the case of cannel gas, has a tendency to smoke, and is easily blown about by currents of air. This is the case also with all union jet flames burned at very low pressures, and practically a jet of this kind cannot be burned much below 0·3 or 0·4 for small sizes, and 0·5 for large sizes consuming four or five cubic feet per hour. Scholl's "Perfecter," as he has called it, has been used extensively in London and other towns for common gas, but it is not suitable for the richer gas used in Scottish towns. It will be observed that the principle is the same as that adopted in the "Concordia" burner, already described and figured.

If two batwing flames are brought together, especially if the slits be narrow, the gas of low quality, and the pressure somewhat high, the illuminating power of the united flame is greatly in excess of the sum of the two tested separately. Upon this principle is constructed a double-slit batwing, the slits being about a millimetre apart, which is used in Manchester and other towns in England, and which is an excellent burner for gas not exceeding 20-candle power, but which gives a somewhat smoky flame with gas of high quality.

The governors attached to batwing or union-jet burners consist of small chambers, placed immediately beneath the burner proper, and containing a disc of metal or steatite, which is raised by the current of gas in such a way as to diminish the channel through which it obtains access to the flame. As the pressure is increased, the disc is raised in a greater degree, and the channel is diminished in proportion. In Mr. Sugg's governor, the disc is of steatite, and there are small guiding and other parts subservient to the better working of the contrivance, which it is not necessary more particularly to describe.

Messrs. Bray, of Leeds, who are manufacturers of burners on a very large scale, make both batwing and union-jet or fishtail forms of excellent quality in relation to their very moderate price. They also make what they have called slit-union burners, in which, although formed by a slit, the shape of the flame resembles that which is furnished by the ordinary union jet. The table-top of Mr. Sugg modifies the shape of the flame in a somewhat similar manner.

The only other batwing that requires further to be noticed is the patent regulating batwing used in the United States, where it was introduced in 1871, and which is practically the only flat-flame burner capable of burning advantageously the "air gas" made by saturating air with the vapour of petroleum spirit. It consists of a very much elongated iron batwing with an exceedingly narrow slit, surrounded by a brass tube at the distance of about two millimetres; into the space between the two gas is admitted by a wide orifice, the amount being regulated by a screw, and this gas ascends entirely without pressure, while the force of the gas issuing from the narrow slit spreads it out into a fine soft flame. This burner gives excellent results with gas of all qualities, but its shape is not adapted to the gas-fittings in use in this country, and it has not been used here except for air gas made for private houses.

CHAPTER XLIII.

RESULTS OF EXPERIMENTAL TESTS IN GAS-LIGHTING.

British Association Gas Reports—Cannel Gas and Common Gas—Evils of Excessive Gas Consumption—Effects of Various Pressures and Quantities with Flat-flame Burners and Cannel Gas—With Argand Burners—Absorption of Light by Globes—Variations in Pressure—Similar Experiments with Common Gas—Effects of Heating the Gas or the Air Supply—Gas Governors—Cost of Burners.

The reports of the British Association committees, already referred to, deal with the respective merits and advantages of most of the foregoing burners, and do so upon a basis of perfectly independent experiment. They may therefore be taken, to a very great extent, as trustworthy guides to consumers.

The reports already issued are two in number. The first of them, which was read at the Dublin meeting, is published in the volume of Transactions for 1878; the second, which was read at the Swansea meeting, was published in the Transactions for 1880. The first committee consisted of Dr. William Wallace, Professor Dittmar, and Mr. Thomas Wills; the second committee consisted of the two first-named gentlemen and Mr. John Pattinson. The first report, which has reference to cannel gas, was drawn up by Dr. Wallace; the second, which has reference to the gas obtained from common coal, was drawn up by Mr. Pattinson.

The first report, presented in 1878, or, as it is more correctly described, the first part of the report taken as a whole, was based upon experiments with the cannel gas in common use in Scotland, which has an illuminating power of 26 candles or thereabouts; the second is based upon experiments with London gas, which has an illuminating power of 16 candles or thereabouts. The practical interest of the former is confined to the dwellers north of the Tweed, as that of the latter to dwellers south of the Tweed; but, as this book is intended to convey information to all, it will be desirable to give a summary of the results obtained with both the forms of gas.

In some introductory observations, the report states that the fact has long been recognised that the illuminating power of coal gas depends largely upon the way in which it is burned. Setting aside all theories about the source of the illumination, whether from solid highly-heated particles of carbon or from incandescent gases, the fact remains that a given quantity of gas may be burned under different conditions, so as to yield widely-different illuminating effects. A gas made from bituminous coal gave, when burned by Sugg's patent improved London argand at the rate of 5 cubic feet per hour, the light of 14·81 candles. The same quantity burned by a union jet at ·5 inch pressure gave 11·46 candles; and by a union jet at 1·5 inch pressure 3·66 candles; these quantities corresponding to 100, 77, and 25. Pattinson states that burners are in extensive use in Newcastle which, for 5 cubic feet of gas, give a light equal to only 3·75 candles; while the same gas, burned in good argand burners, gives for the same consumption 17·75 candles, and in good union or fishtail burners 12·5 candles. In the case of cannel gas, the variations are not so extensive; but the following illustrates the effect of pressure alone in influencing the light obtained, the burners being of the same kind in each case, but with orifices cal-

culated to deliver ·5 cubic feet of gas at the different pressures. At ·5 inch pressure a union jet of the best construction gave a light equal to 28·47 candles, while at 1·5 inch pressure the light from an equally good union jet was 21·14 candles, these numbers being in the proportion of 100 to 74. In these instances the quantities of gas were the same, five cubic feet per hour, but if we take smaller quantities of gas, and calculate the results to five feet, the numbers obtained are still more remarkable. The following is quoted from Wallace's paper on the economic consumption of coal gas, all the burners used being Bray's "adamas-tipped" union jets for cannel gas. A number 0 at 1·5 inch pressure burned two cubic feet per hour, and gave a light of 3·5 candles, or, for five cubic feet per hour, 8·8 candles; a number 8 at 1 inch pressure burned 7·1 cubic feet per hour, and gave 45·4 candles, or for five cubic feet, 32 candles. Between ordinary working limits of pressure, and with equally good burners, we have, therefore, a given quantity of gas, five cubic feet an hour, giving, in the one case, 32 candles, and in the other 8·8, or in the proportion of 100 to 27·5. The loss of light here shown, amounting to 72·5 per cent. of the whole, is exceeded when still higher pressures are used, and it is greater with common that with cannel gas. A remarkable effect is produced from a mixture of cannel gas with about twice its bulk of air. At a low pressure, in an argand jet with large holes, it gives a fairly luminous flame, while, at a high pressure, 3 or 4 inches, although the quantity of gas consumed is three times as great, the flame is almost non-luminous, and has a greenish tint. The gas, used somewhat extensively in the United States, made by saturating air with petroleum spirit, requires to be burned at a pressure not exceeding 0·1 of an inch, which can be obtained only with an argand of very large holes, or a batwing of peculiar construction, called the "American Regulating Batwing."* At ordinary pressures, such as are used for coal gas, there is scarcely any light, and the flame keeps about a quarter of an inch or more above the burner.

It is not only on the score of economy that it is desirable to burn gas in such a manner as to obtain from it the greatest amount of light. The burning of a moderate-sized jet of gas produces as much carbonic anhydride as the breathing of two grown-up men, and as, in an ordinary apartment, we have usually from three to six of these, the air becomes vitiated with remarkable rapidity. It is therefore desirable, in relation to health, to obtain the illumination we require with the least possible expenditure of gas. The sulphur in gas is a very serious drawback to its use. In burning, it is, no doubt, converted chiefly, if not entirely, into sulphurous anhydride, but it is soon further converted into sulphuric acid, which attacks with avidity all the more readily destructible articles in the apartment. So far back as forty years since, the effects of the sulphuric acid arising from the combustion of gas upon the bindings of books and many articles of furniture was noted, and recent experiments have shown that leather, paper, &c., in ill-ventilated apartments exposed to the emanations from burning gas for a series of years, contain very large quantities of sulphuric acid. One of the reporters had occasion recently to investigate the action of burning gas upon cotton goods stored in warehouses in London, Manchester, and other cities and towns, and found that, in some cases, a few months were sufficient to affect certain colours, while within a year enough sulphuric acid was absorbed seriously to injure the strength of the fabrics. No doubt the true

* Described in the last chapter.

remedy for this evil is to ventilate the warehouses; but it is obvious that if the gas were burned in an advantageous manner, and the quantity reduced to one-half or one-third, the damaging effects would be proportionately lessened.

The gas used in the United Kingdom is of several distinct qualities. The best, or Scotch cannel gas, is made only in Scotland, and its average illuminating power may be stated as twenty-six candles for a consumption of five cubic feet per hour. In London a cannel gas, of about twenty-three candles, is used in small proportion, and in Liverpool, Manchester, Carlisle, and probably some other towns, an intermediate gas is manufactured, of about twenty candles. The common gas in use in London, and in most other English and Irish towns, has an illuminating power of from fourteen to sixteen candles. In the reports, the investigations have been confined to the first and last of these varieties—the cannel gas of twenty-six, and the common gas of sixteen candles. In the case of cannel gas, the standard is found by testing the gas by a union jet consuming five cubic feet at a pressure of 0·5 of an inch, while the common gas is tested by Sugg's London Argand, consuming five feet per hour at a pressure of about 0·05 of an inch.

In testing flat flames, the custom has invariably been to present the flat side to the disc of the photometer, but, although the results thus obtained are satisfactory in comparing one flat flame with another, they cannot fairly be compared with those of the flames which give an equal light all round. The edge of a flat flame gives considerably less light than the side, but the difference between the two depends very much upon the richness of the gas, or, in other words, upon the opacity of the flame. A flame of gas of low quality is so transparent that an ordinary newspaper can be read through it, but this cannot be done with a flame of cannel gas except at the lower portion, which in any case offers scarcely any obstruction to the passage of light. The following example may be given. A union jet, consuming five cubic feet of cannel gas at 0·5 inch pressure, gave a light of twenty-seven candles when tested in the ordinary manner with the flat side towards the photometer disc; but the edge gave only twenty-three candles, and when rotated, so as to give the flame every position, the average result was, as nearly as possible, twenty-six candles, showing that the ordinary test gave one candle too much, or nearly four per cent. In the case of paraffin flat-flame lamps, the difference between the front of the flame and the average all-round varies from four to ten per cent. In the latter case, the flame is intensely opaque and of a deep yellow colour. All the figures given in the report refer to the flat side of the flame, and this must be borne in mind in comparing flat with round flames.

A table giving the results obtained with the cannel gas in Bray's union-jet burners, without any means of controlling pressure in the burner itself, showed that the full normal result of twenty-six candles could only be obtained from burners of the largest sizes, absolutely consuming five cubic feet or nearly, and when the pressure did not exceed 0·5 inch. At higher pressures, these large burners began to blow. The small burners, consuming from a little over one foot to a little over four feet per hour, ranged from 8·5 candles to 23·9 candles at 0·5 inch pressure; from 7·6 to 22·46 at one inch; and from 6·8 to 19·73 at 1·5 inch. At the last-named pressure, the three largest burners were disabled by blowing. The reporters believe that the effects of pressure would have been still more remarkable if the gas had been tested at lower pressures than 0·5 inch and at higher pressures than 1·5.

As in practice it is found impossible to distribute gas at a pressure of less than 1·2 or 1·5 of an inch of water, various contrivances for breaking the force of the current have been invented. Among union jets of this kind, the simplest, perhaps, is that of Leoni, consisting of a brass and an iron tube which fit into one another, and between which a thin film of cotton wool is placed. This is a very good burner, but it cannot be depended upon for delivering exact quantities of gas. Bray has constructed a very good burner similar to those already mentioned, but having a double ply of cotton cloth stretched across a metal ring placed in the tube, in order to reduce the pressure. The same manufacturer has more recently invented another burner, in which the reduction of pressure is attained by passing the gas through an orifice in a porcelain plate cemented into the lower part of the burner. He calls these "Special" burners, and they are of two kinds, one intended for general use and the other for street lamps, in which the orifices are somewhat smaller, and in which, consequently, the pressure is further reduced. Morley's patent burner is of brass and vase-shaped, with a porcelain top, and at the bottom one or two small orifices for admitting the gas. Williamson's jet is similar in principle, but more complicated in construction. Da Costa's burner consists of a hollow vase stuffed with iron turnings, into which an ordinary iron union jet is screwed. There are others, but all have the same object in view; and the simpler and cheaper burners, such as Bray's, accomplish it as successfully as those of more complicated construction, and these have, therefore, been selected for a series of comparative trials, all being made with 26-candle gas. Some of the burners referred to are called regulators, but this is a mere name, for it is obvious that they merely obstruct the flow of gas, the quantity delivered rising as the pressure is increased. In Bray's "Special" burners, the two holes forming the "union" jet are placed at an angle of about 120 degrees.

A table of the results obtained by trials of the different sizes of Bray's regulator jets for cannel gas, under the same three pressures as before, shows illumination varying from 8 to 26·4 candles. The best result is obtained with a large burner, consuming 3·8 cubic feet per hour, at the lowest pressure; the worst with a small burner, consuming 2 cubic feet per hour, at the highest pressure. With both series of the "Special" burners, in which the pressure is much reduced by the internal arrangements, the best results were obtained at 1 inch, while at 0·5 inch the flames were sluggish, and in some instances showed a tendency to smoke.

A flame formed by a jet of gas issuing with considerable velocity possesses a certain degree of stiffness, and resists, to some extent, the influence of currents of air. This is particularly necessary in the case of cannel gas, since, whenever the flame is much deflected by air currents, a portion of the carbon arising from the heating of the richer hydro-carbons, *e.g.*, olifines, benzole, &c., passes off unconsumed, and a smoky flame is the result. In practice, it is necessary to sacrifice a certain proportion of the possible illuminating value in order to give the flame sufficient stiffness to resist currents of air.

Next to the union jet, the batwing is that most commonly used for burning gas. It is simply a little tube closed at one end, in which a slit is cut, varying in breadth from about two-tenths of a millimetre to one millimetre. It is made of cast iron, brass, porcelain, or steatite, the best form being that having a brass body and a

steatite top. The flame of the batwing is wider and shorter than that of the union jet, and in order to be equally effective requires to be burnt at lower pressures. It is particularly adapted for large flames burning from 3·5 to 5 cubic feet per hour. With rich cannel gas, twenty-five to thirty candles, it gives results at least equal to the union jet, and with gas of eighteen to twenty-two candles it is decidedly superior.

A series of five steatite batwing burners, manufactured in Germany, and consuming from 1·1 to 4·05 cubic feet per hour, were tested under the three pressures used in the previous experiments, namely, at 0·5, 1·0, and 1·5 inch. At the lowest pressure, the illuminating power ranged from 19·27 candles for the smallest of the series to 23·57 for the largest; at the medium pressure the results were almost the same, but the largest burner was disabled by blowing; and at the highest pressure the illumination of the three smaller sizes was diminished, and the two larger were both disabled.

The considerable loss of light experienced when gas is consumed in batwing burners at any but comparatively low pressures has given rise to many efforts to combine with the jet an apparatus to reduce the pressure of the gas before it issues from the narrow slit. Various burners having obstructions have been constructed, of which Bronner's is one of the best known. It consists of a somewhat pear-shaped brass body, with a steatite top similar to those of which the results have just been given, and at the bottom a small piece of steatite in which there is an oblong slit. There are, for cannel gas, six sizes of bodies, the sizes depending upon the area of the slits, and five sizes of tops; and, as these screw into one another, there are thirty possible combinations. In none of these combinations does the pressure of the gas at the point of ignition exceed 0·5 of an inch with an initial pressure of 1·5 inch, while in some it is only 0·2, and in some it is so low that the flame smokes and is useless. The rate of combustion is dependent upon three conditions—first, the area of the opening at the bottom; second, the area of the slit of the burner; and third, the initial pressure of the gas. The range of combinations renders it possible to select a burner to suit almost any description of gas or any standard of pressure, but the burners are not adapted for lower pressures than one inch. For common gas, *i.e.*, of fourteen to sixteen candles, a different series of tops is provided, in which the areas are considerably greater than those made for cannel gas, and in which the pressure is reduced from 0·1 to 0·3 of an inch. These burners cannot be employed for cannel gas, although with common gas they are exceedingly effective, and are much in use, especially in London.

A table in the report shows the action of each of the thirty combinations, at initial pressures of 1·0 inch and of 1·5 inch, with the 26-candle gas. The full illumination was obtained, or even somewhat exceeded, at 1 inch pressure, with the number 3 burner and the number 4 top, burning 2·13 cubic feet per hour; and with the number 5 burner and the number 6 top, burning 4·3 cubic feet per hour; all the rest falling short of this result, and ranging from 19·36 candles to 25·87. At 1·5 inch initial pressure, an illumination exceeding 27 candles was given by three combinations, number 3 burner with number 5 top, and also with number 6 top, and number 3½ burner with number 6 top. An illumination exceeding 26 candles, but less than 27, was given by five combinations; and in only three out of the whole thirty did the illumination fall below 20 candles. These three were number

2 burner with either number 2 or number 3 top, and number 5 burner with number 2 top. The table shows that it is easy, with properly-adjusted batwing burners, to obtain, with a consumption of from three to five cubic feet per hour, at least the full effect of illumination exhibited in the standard mode of testing, and that, even with a consumption of only two cubic feet, a very favourable result may be obtained. In no case is the loss of light with batwing burners so great as with badly-arranged union jets.

Many other descriptions of improved batwings have been constructed, some of which have been tested. The "Clegg" batwing, manufactured by Sugg, has a steatite top and a conical brass body closed at the bottom, and with a slit cut in it with a fine saw. The respective sizes of the slits above and below determine the consumption of gas, and the pressure at the point of ignition. In Silber's batwing, made by the Silber Light Company, one burner is placed above another, both being of steatite, the slit of the lower one being much smaller than that of the upper, and connected by a vase of brass. Only the three smallest sizes of these are suitable for a rich cannel gas, the larger ones being intended for gas of lower quality. The best of four sizes of the Clegg, at 0·5 of initial pressure, gave 24·92 candles, at 1·0 inch pressure the best gave 24·19 candles, and at 1·5 inch the best gave 23·72 candles. The best of the three small Silbers, at the same three pressures, gave 25·5 candles, 26·17 candles, and 27·2 candles, thus surpassing the performance of the Clegg burners by 0·62 candles at the lower pressure, by 1·98 at the medium pressure, and by 3·48 at the highest pressure.

Several varieties of regulating batwings have been invented by Sugg, Witthoft, Winsor, and others, the principle of their construction being to check the flow of gas by means of a plug regulated by a screw. At a given pressure in the pipes the burner may be regulated to deliver any desired quantity of gas; and in some experiments with the Winsor and Sugg burners they were regulated so as to burn the number of cubic feet per hour corresponding with the number marked on each burner, and for which it was supposed to be specially adapted. The highest result obtained from the Winsor was 25·2 candles, the highest from the Sugg was 24·88 candles. The former was burning five feet per hour, the latter four.

Argand burners are exclusively used in the photometric testing of common gas, and they are also employed rather extensively for lighting shops and public buildings, but to a limited extent for private houses. They give a higher photometric effect with common gas than any flat-flame burner known; and even with cannel gas, the best descriptions, especially those of Sugg and Silber, give results which approach very near to those obtained when the gas is tested at a comparatively low pressure by large-sized fishtail or batwing burners.

The original form of argand was a brass double cylinder, with, above, an iron ring perforated with small holes, and, below, a "crutch," or forked tube, by which the gas was introduced at opposite sides. A wide and short glass chimney was used, but this was afterwards modified in a variety of ways with a view to making the current of air impinge more directly upon the flame, and so increase the intensity of combustion. The holes being small, the gas escaped at comparatively high pressure; and the character of the flame, both as to volume, shape, and luminosity, depended partly upon the initial velocity with which the gas escaped from the burner, and partly upon the shape and dimensions of the funnel. The

enlargement of the holes, allowing the gas to escape at a moderate pressure, was proposed by the late Dr. Letheby, who was afterwards associated with Mr. Sugg, by whom many improvements in argand burners have been introduced. The Letheby burner raised the *apparent* quality of London gas from 12 to 14 candles, and a further increase of 2 candles was obtained by Sugg's London Argand, now generally accepted as the standard burner for testing gas made from common coal. In this burner the principle is recognised of permitting the gas to escape practically without pressure, the shape and volume of the flame being determined by the narrow funnel and a "cone" of thin metal which serves to throw the current of air into close contact with the outside of the flame. The upper portion of the burner is of steatite, and instead of the ordinary crutch below, the gas is introduced by three very narrow tubes. A number of sizes of this burner are made, but the following are the various dimensions of the standard burner used in photometry: diameter of steatite top, external, ·84 inch; internal, ·47 inch; number of holes, 24; diameter of holes, ·04 inch; the chimney 6 by 1·75 inches for gas of 14 candles, and 6 by 2 inches for gas of 16 candles. The narrow chimney and the cone restrict the quantity of air to very little more than is required to burn the gas, thus avoiding the diminution of light which results from a too rapid combustion, and also from the cooling effect of a large quantity of air. The pressure of the gas inside the steatite top is considerably less than 0·1 inch, and that required to pass 5 feet per hour through the complete burner is 0·2 inch.

In the burner introduced by Mr. A. M. Silber the steatite top with wide holes, about 1 millimetre or 0·04 inch, is also adopted, but the body of the burner is considerably prolonged, and the so-called "cone" is long and cylindrical, with a curved top. A very essential feature in the Silber argand is an air-tube introduced into the centre of the jet, which is said to carry a portion of the air to the upper part of the flame, and which certainly has a remarkable effect in steadying it. The chimney is 7 or 8 by 1·75 inches, and, in consequence of the form of the "cone," is kept so cool at the bottom that it may be handled without difficulty while the flame is burning. Funnels of 10 inches high are also used, but while the consumption of gas is thereby increased, the illuminating power per cubic foot of gas remains almost constant. Mr. Silber has recently discovered the remarkable fact that a globe or vase, placed below his argand, increases the illuminating power considerably; and his statement has been verified both as to common and to cannel gas, the increase with the former being about one candle, with the latter about a candle and a half. The effect of placing a vase below an ordinary union jet was also tried, but no increase of light was obtained, while the flame showed a distinct tendency to "blow." That the flame of the argand should have its illuminating power increased 6 per cent. by passing the gas through a glass vase, or cylindrical metal box, which answers the purpose equally well, is a phenomenon which appears to be at present incapable of explanation.

Photometric tests were applied to nine varieties of argand with cannel gas of 26-candle power. From 3 to 4 cubic feet of gas per hour were burned in each case, and the results calculated to the usual standard of 5 feet. The worst performance was that of a German porcelain argand, with cone and 40 small holes, which gave only 17·80 candles. Excepting the Silber burners, the best was Sugg's London argand, with 24 holes, cone, and regulator, which gave 22·40 candles. The Silber

burners came next, each fitted with steatite top, cone, and central tube. That with 40 holes was only a fraction better than the London argand, giving 22·54 candles. The 32 hole burner gave 23·08 candles, the 24 hole gave 24·04, and the latter, with glass vase beneath, gave 25·61, thus surpassing the London argand by 3·21 candles, and affording nearly the full amount of light which the gas was capable of giving. In another series of trials, the Silber argand was again a little in advance of the best Sugg, and 1·5 candle in advance of that which had the same consumption. It must be remembered that none of these burners were constructed for cannel, but all for common gas; although the performance of the Silber burner shows that it is well adapted for the former also.

Experiments were made to ascertain the loss of light resulting from the use of globes of different kinds and of various shapes. The loss is always considerable, and in many cases excessive, and it results partly from the absorption of light from the material of the globe and partly from the draught caused by the ascension of the heated air in the confined space. As regards material, a piece of clear window glass held in front of a gas flame diminishes the light to the extent of about 10 per cent.; but in the case of a clear globe the loss is in some cases less, owing to the reflection from the surface farthest from the photometer. Globes frosted or ground all over, technically known as "moons," absorb about 25 per cent. of the light when well shaped, and opal, or "cornelian," globes 40 to 50 per cent., according to the thickness and quality of the glass. The following results were obtained with globes of different sizes ground all over, and show the effect of increased draught in diminishing the light :—

A 6-inch	globe	caused	a loss of	25	per cent.
A 7·5-inch	,,	,,	,,	27·5	,,
A 10-inch	,,	,,	,,	38	,,

All these globes had the usual sized opening below, about 1·75 inch in diameter.

Experiments were made with clear 7·5-inch globes, having openings below varying from 2⅜ inches to 1 inch in diameter. The source of light was a Bronner batwing, No. 5 top, No. 4 bottom, burning under a pressure of 1 inch 3·35 cubic feet of gas. The naked flame gave a light of 16·8 candles, and it was then tested behind a succession of clear globes, differing only in the diameter of the lower opening. With an opening of 2·375 inches, the light was 15·4 candles, or a loss of 8·3 per cent.; with 2·25 inches, it was 15·2 candles, or a loss of 9·5 per cent.; with 2 inches, 13·6 candles, or 19 per cent.; with 1·5 inch, 13 candles, or 22·6 per cent.; and with 1 inch, 12 candles, or 28·6 per cent. With the two larger sized openings the flame was perfectly steady, with the 2-inch opening there was a slight flicker caused by the draught; this was more marked with the 1·5-inch opening, making the flame practically useless as a source of light. It is evident, therefore, that the openings of the globes should be as wide as possible, and not less than 2·5 inches. The cornelian globes used in Bronner's system of gas-lighting have an opening of 2·375 inches in diameter; and Sugg has introduced globes of similar material, which he calls albatrine, but with openings of 4·125 inches in diameter. These globes are constructed of various sizes to suit certain burners, both batwing and argand, and the combinations are known by certain names, as the "Westminster," "Viennese," "Frankfort," "Italienne," "Parisienne," &c. Some of

these arrangements are fitted with argands, and some with batwings, and some have attached to them regulators with the intention of maintaining a constant pressure.

One of the difficulties connected with gas illumination is that the pressure in the mains varies considerably in different parts of a town, and at different hours of the day and night. One result is that a system of lighting adapted for a part of a town situated at a low level will show inferior results in a more elevated situation. A rise of 10 feet gives, roughly, a tenth of an inch of increase of pressure, so that it may easily happen that in the same town or city the pressure in one place may be one inch, while in another it may be 2·5 inches. Again, the pressure of the gas, as sent out from the gasworks, is altered from time to time in accordance with the consumption; and as public works, shops, &c., are suddenly lit up or extinguished at certain hours, private consumers are annoyed in the one case by a sudden falling-off in the amount of light, and in the other by a flaring flame and hissing sound, both of which are very irritating. The cure for these evils is found in the use of governors or regulators. Every district of a town, the elevation of which is such as to affect appreciably the pressure of the gas, should have a governor, which may either be self-acting, to maintain a constant pressure throughout the day, or to vary sympathetically with the governor at the gasworks. Many of these have been invented, among which may be mentioned those of Cathels, Peebles, and Foulis. The pressure in the mains should not be reduced below 1·2 or 1·4 of an inch, but, inasmuch as anything more than that is too high a pressure for the economical burning of gas, each house should have a regulator in order to reduce the pressure constantly to about 0·7 or 0·8. Some of these regulators are dependent on the action of the gas upon a broad leather disc, attached to which is a ball and socket valve, while others have metal or glass bells floating in mercury, and acting upon a valve of the same kind. Both of these work satisfactorily. Among the best dry regulators are those of Sugg of London, and Peebles of Edinburgh, while probably the best mercurial regulator is that of Busch of Oldham. In the case of public works and other buildings consisting of several floors, a regulator should be placed in each floor, and one should be placed on each street lamp, for which a special form is constructed. The best street-lamp regulators made in this country are those of Peebles and Sugg, but a very admirable little instrument called a rheometer is extensively used in Paris, and has been tried with tolerably successful results in several of our own cities. It is the invention of M. Giraud of Paris, and it differs from the regulators which maintain a constant pressure in delivering a constant volume of gas, with any size of burner, and under any pressure, provided that this is not less than 0·7 or 0·8, and that the burner is sufficiently large to pass the requisite quantity. The recently-invented "Needle" governor of Peebles is similar in principle, and maintains a given volume of gas with remarkable constancy.

The second part of the report, which was presented at the meeting of the Association at Swansea, deals with the burning of what is known as common gas, or gas made from the common bituminous coal of the Newcastle and other coal-fields, or from this class of coal mixed with a small quantity of cannel coal, and having an illuminating power equal to sixteen standard sperm candles when consumed at the rate of five cubic feet per hour in Sugg's No. 1 London Argand burner, the standard burner adopted in London by the London gas referees, and

prescribed in nearly all the recent Acts of Parliament of gas companies. This quality of gas, or gas varying from fourteen to sixteen candles illuminating power, is chiefly used in London, and in most towns in England and Ireland.

The principal condition to be observed, in order to develop the maximum amount of light from coal gas, is to supply the flame in *a suitable manner* with just a sufficient amount of air to effect the complete combustion of the gas. If coal gas is lighted as it issues under a low pressure from the end of a gas-pipe from which the burner has been removed, it burns with a long irregular-shaped flame, giving off much smoke, and yielding a dull yellowish light of very little intensity. The gas has to ascend to a considerable height before it meets with sufficient air to consume it completely, and the upward currents created by the heat waft the languid flame about in all directions, and cause it to give off smoky particles. On the other hand, if the gas is forced under considerable pressure through a very small orifice or very narrow slit, it burns with a thin bluish flame, without visible smoke, and yielding very little light. The small rapid stream of gas, by virtue of the force with which it issues, becomes mixed all at once with such an excessive amount of air that the carbonaceous constituents of the gas, instead of being partially separated and made incandescent, are converted at once into carbonic acid in a flame having little or no luminosity, just as when gas is burned in a Bunsen burner. These illustrate two cases in which air is supplied to a flame in an unsuitable manner, one in which air is supplied too slowly, and the other in which it is too rapidly mixed with the gas. As in flat-flame burners the air-supply is chiefly regulated by means of the pressure under which the gas is allowed to issue, it is necessary to avoid these two extremes in order to develop the light-giving properties of the gas. The dimensions of the orifice through which the gas issues from such burners, and the velocity with which it issues, should be so adapted to each other that the gas in burning is brought into contact with the air in such a manner that the heat developed from a portion of the burning gas raises the remainder to a high state of incandescence before it is ultimately entirely oxidised. The quality of a flat-flame burner depends almost entirely upon the extent to which this condition is fulfilled. In argand burners, or at any rate in those of the best construction, the due supply of air is admitted to the interior and exterior of the cylinder of flame, and regulated by means of the chimney and cone, the gas being allowed to issue from the burner under little or no pressure. A more complete control is thus obtained over the air-supply than is possible in the case of flat-flame burners, and it is probably on this account that more light can be developed from common gas when burned in good argand burners than when burned in ordinary quantities in flat-flame burners.

The effect of the pressure under which gas is caused to issue upon the air-supply, and consequently the amount of light emitted, was shown by the results of a series of experiments made with union jet and batwing burners having orifices of various dimensions, and unprovided with any means of checking pressure. The gas was caused to pass through them at different pressures by means of a weighted gas-holder, and was equal to sixteen candles when tested in the usual manner with the London argand. The union jets employed were of three sizes, the smaller with holes of 0·024 inch in diameter, the medium with holes 0·032 inch in diameter, and the largest with holes 0·043 inch in diameter. The tables of the results are lengthy,

but it was shown that the small quantity of gas passing through No. 1 jet became so mixed with air that even at 0·5 inch pressure the light emitted when burning 1·6 cubic feet per hour was only equal to one candle, or 3·1 candles when calculated for 5 feet consumption of gas. When the pressure was increased to 1·5 inches the results were still worse, for 3·2 cubic feet of gas per hour were burned with the production of light equal to 1·2 candle, or only 1·9 candle per 5 cubic feet of gas. With the larger-sized union jets, the results were better, No. 6, when consuming 3·8 cubic feet of gas at 0·5 inch pressure, giving a light equal to 9·6 candles per 5 feet of gas. This amount of gas, 3·8 cubic feet, when issuing under 0·5 pressure, is not mixed with so much air as the 3·2 cubic feet issuing under a pressure of 1·5 inch from the No. 1 burner.

Four batwings were used in the experiments—No. 2, with a slit 0·008 inch wide; No. 4, with a slit 0·012 inch wide; No. 6, with a slit 0·014 inch wide; and a fourth, not designated by a number, with a slit 0·020 inch wide. On comparing the result of burning 5·4 cubic feet of gas, issuing from No. 2 batwing under a pressure of 1·5 inch with the result of burning the amounts of gas nearest to this amount in the case of each of the other burners, it was seen that the illuminating power increases as the pressure required to send the desired amount of gas through the burner decreases, or, in other words, the illuminating power is increased as the gas, issuing with less velocity, is thus mixed or brought into contact with less air.

It was also observed, taking both series of experiments, that in the case of each burner there is a certain consumption and a certain pressure which give the best result, and that at all other consumptions and pressures above or below this the results are worse. No. 6 union jet, for instance, gave the best result when consuming 3·8 cubic feet of gas under 0·5 inch pressure; No. 2 batwing gave the best result when consuming 2·8 cubic feet under 0·7 inch pressure; No. 6 batwing the best result when consuming 4·7 feet of gas under 0·7 inch pressure; and the large batwing when consuming 9·3 cubic feet under 1·2 inch pressure. There is, therefore, a limit to the increase of the illuminating power by reduction of pressure, and this limit is reached when the flame ceases to have a somewhat definite form, and burns in a languid, waving manner, showing very low intensity of combustion, and having a tendency to smoke. In such cases the air is not supplied sufficiently for vigorous and intense combustion. This condition is especially illustrated in the case of the batwing burners. With each of these, the gas issuing under the lowest pressures used produced less light than when higher pressures were used. Thus, for instance, No. 6 burner gave a light equal to only 9·3 candles per 5 cubic feet when the gas issued under a pressure of 0·3 inch, and this was increased to 13·5 candles per 5 cubic feet when the pressure was increased to 0·7 inch. Again, with the large batwing having a slit 0·020 inch wide, the gas issuing at a pressure of 0·4 inch gave light equal to 14·2 candles per 5 cubic feet; whilst under a pressure of 1·2 inch the gas gave a light equal to 16·6 candles per 5 cubic feet; a result even better than that of the standard burner.

Another point noticed in the experiments was, that as larger burners are used, and larger quantities of gas burned, the illuminating power per 5 cubic feet increases. Although the chief cause of this improvement is the better apportionment of the gas-supply to the air as regulated by pressure, yet the increased volume of flame, causing greater intensity of combustion, and preventing the cooling of the

flame by the surrounding atmosphere, is doubtless another cause which contributes to the production of the improved result.

It has often been asserted that if gas be heated before it is burned the illuminating power is improved, and some experiments made in the laboratory of the University of Munich appeared to show that an increase of 18 per cent. in the illuminating power was produced by heating the gas from 64.5 degrees to 288 degrees Fahrenheit. The London gas referees, in an able report on the construction of gas burners, issued in 1871, repeated this experiment, and found no appreciable difference in the illuminating power of gas on heating it before burning from about 69 degrees to 296 degrees Fahrenheit. One of the reporters has recently tried the same experiment. The gas was caused to pass through about six feet of copper tubing, heated to dull redness, and by this means it was heated from 58 degrees up to 350 degrees, as indicated by a thermometer placed in the current of gas within six inches of the burner. It was found necessary to open wider the tap of the meter as the temperature rose, in order to pass exactly the required quantity of 5 cubic feet per hour, the heated and expanded gas requiring more time to pass through the burner than the same quantity of cold gas. Careful observations were made of the illuminating power as the temperature rose. The result was that no appreciable difference could be seen in the illuminating power even at the highest temperature reached, 350 degrees of Fahrenheit, thus confirming the results obtained by the London gas referees. As the temperature of combustion would be increased by heating the gas, and consequently a higher degree of incandescence produced, some increase of the illuminating power might be expected, but the increase of temperature tried (and it is very difficult to heat the gas even so high as 350 degrees) is evidently too insignificant to produce any appreciable increase in the illuminating power.*

An experiment to try the effect of heating the air supplied to the burner was more successful. The air was supplied from a holder under pressure. It was passed through a heated copper tube, and thence into the bottom of the standard argand burner, which was closed, excepting to the admission of the heated air. A thermometer was fixed in the current of air about six inches from the burner. There was no difficulty in heating the air to a temperature of 520 degrees Fahrenheit. At this heat the soldering of the apparatus gave way, so that no higher temperature was tried. The temperature of the unheated air was 70 degrees, and the gas used, when supplied with air of this temperature, gave a light equal to 16 candles per 5 cubic feet per hour. As the temperature of the air was increased, the illuminating power gradually rose, until at 520 degrees a light equal to 17·5 candles was produced, being a rise of a candle and a half, or about 9 per cent., for an increase of 450 degrees in the temperature of the air-supply. As the amount of heat supplied by the heated air brought into contact with the gas and the flame is considerable, an appreciable effect is produced on the temperature of the flame, and consequently on its illuminating power. It would appear, however, that the principle of heating the air-supply is not likely to be adopted for general lighting purposes, for the additional light which any practical amount of heating would obtain would probably not afford compensation for the cost and trouble attending the use of the required apparatus.

* This conclusion appears somewhat modified by the more recent experiments of Messrs. Siemens, the results of which are described in the next chapter.

A number of burners of various kinds, now supplied to the public, were tested with common coal gas, having an illuminating power equal to 16 sperm candles, in the ordinary way; and, for convenience of comparison, the results obtained were calculated into the amount of light for a consumption of 5 cubic feet per hour in each case.

Messrs. Bray & Co. manufacture a great variety of flat-flame burners. Their regulator burner checks the pressure of gas in the mains by means of layers of muslin inserted in the burner. Their "special" burner, in addition to the layers of muslin, has also a piece of a kind of porcelain, containing a round hole of less area that the exit orifices, placed below the muslin, through which the gas passes into the burner. These "regulator" and "special" burners are made in three different forms—union jets, batwing, and a modification of the batwing called a slit-union. The latter, owing to a peculiar chambering out of the head of the burner, forms a narrower and higher flame than the ordinary batwing, and is therefore better adapted for use in globes. This form of batwing is also made by various other makers. Besides the burners already mentioned, Messrs. Bray make each form of burner of high lighting-power and of medium lighting-power, and they recommend the medium lighting-power burner in preference to the others for general use, as having less tendency to smoke.

The tables in which the results are conveyed are too lengthy for quotation, but the most important of the facts stated may be briefly summarised. The burners selected were the "medium lighting-power regulator union jets," the medium "special union jets," the medium "special slit-unions," the "high lighting-power special union jets," the "high lighting-power special slit-unions," and the "high lighting-power special batwings." Bray's street and market burners were also tested, but these have no bearing upon the object of this treatise.

The reporters point out that some of the union-jet burners of the smaller sizes give very poor results with common gas; and the tables show that, with the medium power regulator unions, No. 6 has to be reached before, at the most advantageous pressure, a light of 10·4 candles is obtained. With the medium power "special" union-jets, No. 5 is about equally good; and with the medium power "special" slit-unions the same illumination is given by No. 1, rising to 15·3 candles in the case of No. 9, by which, however, in order to attain this result, the absolute consumption of gas is 7·6 feet per hour. The high lighting-power "special" union jets do not differ materially from the last named, but such difference as exists is slightly in their favour. The high lighting-power "special slit-unions" range from 12 candles for No. 4, consuming 3·2 feet of gas at 0·5 inch pressure, to the full 16 candles for No. 9, consuming 10·8 feet at 1·5 inch pressure. The performance of the "special" batwing is very close to this; and generally it may be said that the larger burners are superior to the smaller ones of the series, and that nearly all of them give the best results when consuming from 5 feet of gas per hour upwards to 10 feet or more. They do not appear to meet the requirements of the small consumer, however well adapted for lighting up large rooms or manufactories.

The Silber Light Company make flat-flame burners in three forms—single, double, and triple batwings. A wedge-shaped piece of brass is inserted between the heads of the two latter, for the purpose of directing air-currents to the flame. The body of the burner in each case is large and vase-shaped.

Of these burners it may be said, generally, that they give indifferent results at low pressure, 0·5 of an inch, good results with a pressure of 1 inch, and excellent results with a pressure of 1·5 inch. The double burners give smoky, sluggish flames at 0·5 inch, and the triple ones even at 1 inch. At the high pressure, however, all the triple burners give more than 16 candles, and are very powerful illuminants. For absolute consumptions of 11, 11·5, and 13·1 feet, they give 36·2, 38, and 43·5 candles respectively, and thus seem to produce more light from the gas than any of the other forms which have been examined.

Sugg's "table-top" burner, already described, is fitted with an independent governor as part of its construction, and one of these burners, with a pressure in the mains of 2 inches, consuming 12·3 feet of gas per hour, gave the light of 41·8 candles, or 17 candles when reduced to the 5-foot standard. Another of the same kind, under the same pressure, gave only 15 candles, so that, in all probability, slight differences in the contained governor may be sufficient to confer upon each burner an individual character and capacity of its own.

A variety of forms of Bronner's burners, already described under the cannel gas part of the report, were tested also for common gas, but did not appear to offer any particular advantages. They are of two kinds—the A-top burners, intended for use in globes with common gas; and the B-top burners, intended for use without globes. The best performance of the former did not exceed 13·7 candles, while that of the latter reached 15·7 candles.

Harrison's "Gas-light Improver" is a device similar to that of Scholl applied to union jets. It consists of a small plate of thin iron placed across the top of the union jet burner, against which the jets of gas impinge, thereby checking the force with which they mingle with the air. When the "improver" is applied to a burner with small holes, and when the gas issues under considerable pressure, the light results are better than when no "improver" is applied, but it produces no improvement if applied to a good burner of the same kind in which the pressure has been already checked.

Of argand burners, those manufactured by Silber and Sugg were tested, each one with the consumption of gas for which it is best fitted, that is, with the largest quantity which it will burn without smoking. By carefully controlling and directing the air-supply, as in these burners, much better results can be obtained than with the standard argand used in testing.

The Silber argand tried was one marked B. It was used with chimneys of different heights, by means of which various quantities of gas could be consumed. With a 5-inch chimney, the consumption was 4·3 cubic feet, the total illumination 14·1 candles, and the illumination per 5 cubic feet was 16·4 candles. With a 7-inch chimney, the consumption was 5·7 cubic feet, the total illumination 21 candles, and the illumination per 5 feet was 18·4 candles. Chimneys of 8, 9, and 10 inches raised the total consumption to 6·4 feet for the first and 7·1 feet for the two last, and gave total illumination of 23·8, 26·2, and 26·6 candles respectively. The illumination per 5 feet of gas was 18·6 candles, 18·5, and 18·7.

Of the Sugg argands, a series was taken, of the kind known as Sugg's New Reading-lamp Argands. Each burner is fitted with a separate governor, to control the pressure of the gas in the mains. The series consisted of ten burners, dis-

tinguished as A, B, C, D, E, F, G, H, J, and K, and they had respectively fifteen, eighteen, twenty-one, twenty-four, twenty-seven, thirty, thirty-three, thirty-six, thirty-nine, and forty-two holes for the issue of the gas. The chimneys of the first three were 6 inches in height; of the second three, 7 inches; of burner G, 8 inches; and of the last three, 9 inches. The absolute consumption of gas ranged from 3·2 feet to 8·5 feet, the absolute illumination from 9·6 candles to 30·9 candles, and the illumination per 5 cubic feet reached 18 candles in burner D, 18·3 in G, and 18·2 in K, the remainder ranging from 15 to 17·9. The comparison was therefore slightly in favour of the Silber as against any of the Sugg series, though not enough to make any practical difference. The report does not mention whether the vase under the burner, which gave such remarkable results with cannel gas, was tried with common gas or not.

Although a greater amount of light can be obtained from the burning of common gas in ordinary quantities in good argand burners than can be obtained by the use of flat-flame burners, the reporters are of opinion that there are many reasons for thinking that the latter are better adapted for general use, and that they will continue to be much more used for general lighting purposes than argands. In the first place, the first cost of the argand burner is necessarily very much greater. The cost of maintenance, replacing broken chimneys, &c., is also very much greater. Then, again, the cleaning of the chimneys is troublesome. They must be kept clean, or a loss of light will result. A chimney which had been in constant use for thirty hours, burning Newcastle gas, was so dimmed, by the deposition of what is probably sulphate of ammonia on the inside, that half a candle of the light was intercepted. If, from the irregularities of the pressure of gas in the main, or from other cause, a larger amount of gas is passed through the burner than can be thoroughly consumed, the flame gives off dense smoke, which, if not at once stopped, produces very disastrous effects in rooms. Hence it is almost absolutely necessary to use a special governor to each burner, which adds still more to the cost. It is only when the consumption of gas for which the argand burner is specially adapted is used, that the higher illuminating results are obtained. With smaller amounts, the loss of light by the excessive supply of air which then enters the chimney is much greater than in the case of flat-flame burners of good quality. In the standard argand, for example, by reducing the consumption of gas from 5 to 2·5 feet per hour, the illuminating power was reduced from 16 candles to 5 candles for 5 cubic feet.

The amount of light lost for illuminating purposes by the use of globes was referred to in the first part of the report. In many cases this loss is considerable, and the use of globes with narrow openings, and made of very opaque white glass, should be avoided. The principal advantage of the use of globes is that the direct glare of the flame is prevented, and the light is softened and diffused in a pleasant manner. It is often worth the sacrifice of a portion of the light to produce this effect. With properly-made globes of thin milk-white glass, having openings of not less than four inches at the bottom, and still wider ones at the top, the loss of light can be to a great extent avoided, the light being reflected by the white surfaces of the interior of the globe through the wide openings both upwards and downwards.

From what has been frequently shown in the report, it will be seen how very important it is to have complete control of the pressure at which the gas is supplied

to the burners, in order to develop its light-giving properties to the best advantage. The first part of the report points out the various causes which give rise to the great fluctuations of the pressure in the gas-mains. In many towns, the pressure may vary from less than an inch to four inches. No doubt the pressure as supplied to the burners can be regulated by taps at the burners or at the meter, but in many situations, where the pressure alters much in the course of a single night, this is very troublesome to attend to, and in most cases will be neglected. It is best in such places to have governors which act automatically by the pressure of the gas.

Besides the various governors already mentioned suitable for a number of lights, it is now possible to obtain governors suitable to be applied to single lights at a cost within the reach of most gas-consumers. These are placed near the burner, and in many cases form a part of the burner. In situations which are subject to great variations of pressure, it is worth while on the score of economy to adopt such burners. Vastly different amounts of gas are passed, often imperceptibly, through the same burner. In most of the burners tested for the purposes of the report, and which were not provided with means for checking pressure, the tables show that about twice as much gas passed through the burner at 1·5 inch pressure as passed through at 0·5 inch pressure, and the pressure in the mains often varies more than this. The amounts of gas passed through a burner without obstruction for checking pressure, with and without a governor, were as follows:—With a governor, the gas passed through the burner amounted to 2·6 cubic feet per hour when the pressure in the main was 0·5 inch, and rose to 4 cubic feet when the pressure in the main was increased to 1 inch. Further increments of pressure, successively to 2 and 3 inches, produced no effect. Without a governor, the consumption of gas per hour was 4·9 cubic feet with 0·5 inch pressure, and this rose to 7·4 feet at 1 inch, to 11·8 feet at 2 inches, and to 15·6 feet at 3 inches. Roughly speaking, therefore, in the case of this burner, a governor would save 1,000 cubic feet of gas in every ninety hours of use under high pressure.

Single-burner governors are now made by Sugg, Peebles, Wright, Borradaile, and others. Many of them regulate the pressure by the rising and falling of a small cup, or cone, fitted loosely in a receptacle through which the gas passes on its way to the burner, and they are of a size which does not obstruct the downward light, and of a form which does not offend the eye. Several of these have been tested at pressures varying from half an inch to three inches. From the exigencies of their construction, they do not act absolutely perfectly, but at pressures varying from one inch, at which most of them are constructed to commence to act, to three inches, the amount of gas they allow to pass to the burner does not vary more than half a cubic foot per hour. Such governors are of very great service, not only in preventing waste of gas, but also in very nearly securing what is so essential to the development of the maximum amount of light, a uniform supply of gas to the burner.

The reports of which I have thus presented the substance in a condensed form, exceedingly instructive and no doubt entirely trustworthy as they are, yet leave untouched several points of interest, which it is possible the committee of the Association may see their way to deal with on some future occasion. One of these, for example, is the question of the relative durability of different burners; a question upon which the most discrepant statements are made by manufacturers.

One will assert that his burners are practically everlasting; another, that the proper duration of life of a burner ranges from three months to twelve, and that they ought to be frequently replaced, as their efficiency undergoes diminution. It is manifest that a high-priced burner, if it is not calculated to be also a durable one, may save a certain amount of gas and may yet be an expensive luxury instead of a source of economy; so that the consumer, when told that burner A will give the same illumination as burner B, but with 15 per cent. less consumption of gas, should ask how long burner A will remain in a position to do this if in constant use, and also what is its cost as compared with the other. It might often happen that the saving of gas, although real enough, was not sufficient to compensate the consumer for the higher price of the burner by which this saving was to be effected. Messrs. Bray, for instance, who sell burners at such a price that they can be supplied retail for about fourpence apiece, think that a burner ought not to be expected to consume, during its whole life, more than say a thousand feet of gas; and hence, on this calculation, one which cost eightpence ought to effect a saving of cent. per cent. in order to stand upon the same level with the first; or should consume double the quantity of gas with the same degree of efficiency and economy.

When regarded from this point of view, the batwing burners stand at a marked advantage as compared with the ordinary union jets. The surface of the union jet is a little cup or concavity, in which two fine openings are drilled, and the cup forms a convenient receptacle for small particles of air-borne dust, which collect within it and are difficult to remove. Such particles interfere with the issuing streams of gas, and check the activity of combustion, and on this account they furnish surfaces upon which unconsumed carbon may be deposited. It follows that a union jet, however excellent when it is clean and brand new, soon begins to fall off in its performances, and becomes decidedly inferior to other forms. On account of the cup-shaped surface, and of the position of the orifices, the accumulations of dirt referred to are difficult to remove. With the batwing, on the other hand, the orifice being a slit on a convex or globular surface, the tendency of air-borne dust is to fall away from it; and, whenever any particle does alight actually within the edges of the slit, it can be removed in an instant by passing the edge of a strip of writing paper between the margins. The results stated in the report must be regarded as applying only to unclogged burners; and the union jets are clogged often, and can only be cleaned with trouble and difficulty, while the batwings are little liable to be clogged at all, and whenever they become so can be cleaned in an instant. They therefore, practically speaking, retain their usefulness very much longer than the others, and are greatly to be preferred where there are numerous lights in constant use, to which it would be difficult to pay individual attention. The original forms of batwing, on account of the wide spreading of their flames, were almost prohibitory of the use of globes; but the modern forms described in the foregoing pages, either by modifications in the shape and extent of the slit, or by means of the "table-top" introduced by Mr. Sugg, afford higher and narrower flames, with which globes may be used whenever it is desired.

CHAPTER XLIV.

RECENT INVENTIONS AND IMPROVEMENTS IN GAS-LIGHTING.

Ventilating Burners—The Globe Light—Siemens' Regenerative Burner for Heating the Gas and Air—Grimston's Burner—Various Incandescent Burners—Methods of Enriching Gas by addition of Hydro-carbons.

THE various fittings by which gas-burners are suspended, or to which they are attached, are so widely known that it would be superfluous to describe them with minuteness. They vary from the simplest and cheapest forms to some that are costly and elaborate, and they are made either to depend from the ceiling, to be attached to walls, or to stand upon tables. In the first case they usually slide up and down; in the second they turn on pivots near their attachments, and are composed of one, two, or three arms, according to requirements; while in the third they may be either fixed or movable. If movable, they are supplied with gas through flexible tubes, proceeding either from stationary burners or from some convenient points in the wall or ceiling of the room. They all consist essentially of tube and burner, and their variations are chiefly in the number of lights which they are required to carry, or in the extent to which they take part in the general plan of decoration.

There are, however, some useful forms of gas-burners which cannot be considered separately from their pendants or supports, and the most important of these are the "Globe" light of Mr. Hammond (shown in Fig. 195), and the new "Regenerative" gas-burner invented by the brothers Siemens.

A variety of attempts have been made by many inventors to carry off from gas-lighted rooms the noxious products of combustion, and, at the same time, to provide a sufficient outlet for the air vitiated by respiration. Among the first of these attempts was an arrangement devised by the late Mr. De la Garde, of Exeter, for a literary institution in that city. The room was lighted by argand gas-burners, and Mr. De la Garde suspended over each a tube of about twice its calibre, which received the products of combustion by a trumpet-shaped mouth, placed about two inches above the top of the chimney-glass. This first tube was carried up nearly to the ceiling, a little below which it entered for an inch or two into another tube of similar construction, but of somewhat larger calibre, opening either directly into the air or into a chimney. In this way the mouths of the upper tubes afforded outlet for the air of the room, while the gases produced by combustion were carried up through both tubes, and escaped. The apparatus was said to be successful in its operation, but no one could deny that it was unsightly.

The "Globe" light of Mr. Hammond produces results very similar to those of Mr. De la Garde's contrivance, and has the advantage of being easily rendered ornamental. Its operation will be understood by the sectional drawing given in Fig. 194. The air of the room in which the light is fixed enters near the top of the globe at A, and, passing between the interior of the globe and the

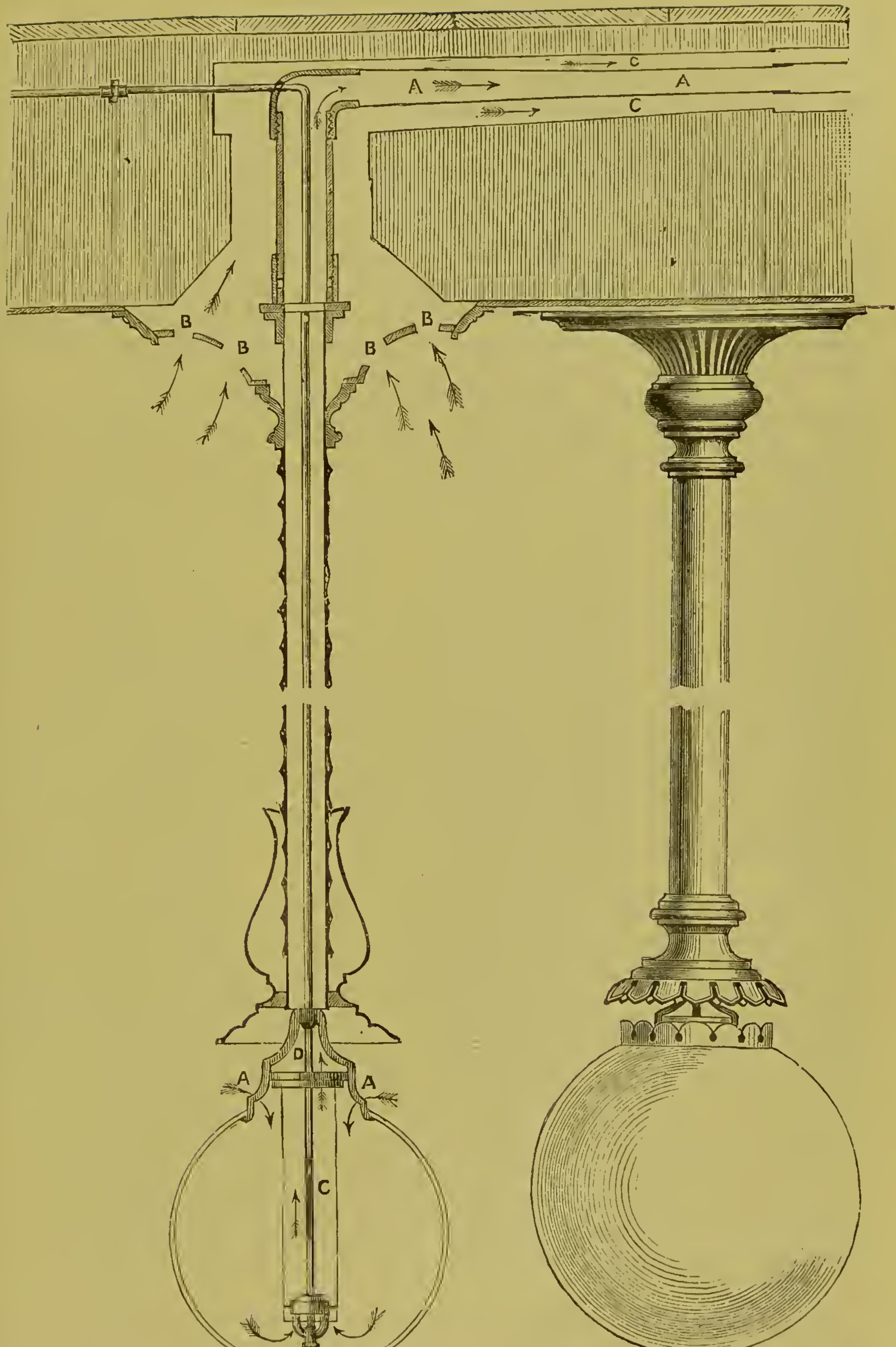


Fig. 194.

Fig. 195.

THE GLOBE LIGHT.

exterior of the chimney-glass, descends to supply oxygen to the burner B. The products of combustion ascend to the top of the chimney-glass at D, under the aperture of the hollow pendant, up which they are impelled by the sharp draught of the heated current. Having reached the upper part of the pendant, the heated products are turned by the elbow at the top into the horizontal pipe A A, and are carried into the chimney of the room in which the light is fixed.

The pipe A A is surrounded by an outer pipe, C C, which affords—where the draught in the chimney is sufficiently good—a means of gently and imperceptibly changing the atmosphere of the room by the steady current which is produced by the heat of the inner pipe. The openings B B, provided in the ceiling-rose for the purpose, communicate through the cone with this pipe, so that the temperature of the room is equalised by the constant gradual rise of the comparatively cool air from below as fast as the upper portion passes into the pipe. This action is self-regulating, the current being more rapid when gently heated, and less so as the cooler air ascends.

Burners of the same kind are made to project from the walls of rooms near the fireplace, the hollow pendants curving downwards from their points of fixation.

The actual burners employed are essentially argands, but of peculiar construction. As will be seen in Fig. 194, the supply-pipe descends to them from above, and passes through the ring of the burner to enter a curved cross-pipe, the extremities of which deliver the gas into a small chamber below its apertures of final exit for combustion. In this chamber it is able to expand, and to lose a portion of the pressure to which it was previously subjected, much in the same way as in the Silber batwing. Lighting is accomplished by passing down a spirit-torch or wax taper from above the top of the chimney-glass; and the supply of gas is usually regulated by a tap in some convenient position, at a distance from the burner.

I am not aware of any experiments for the determination of the amount of light which this burner furnishes for its consumption, but it certainly yields light of a pleasant quality, and is well adapted for the illumination of a room for general purposes. It would hardly be sufficient for fine work, or for reading small print with the maximum of comfort. As a ventilating arrangement it is highly satisfactory; and perhaps the chief objection to its general use would be on the score of price. The burner figured in Fig. 15 would cost £5 9s. 6d. in its simplest form, and more elaborate forms would, of course, be costly in comparison.

For office use, the pendants are fitted with white shades, open below, instead of with globes, so as to obviate the loss of light occasioned by the latter.

The passage of the horizontal pipe between the ceiling of the room which is lighted and the floor of the room above sometimes renders the latter perceptibly warm, but this heating never reaches a point of danger, and may often be an advantage.

The Siemens regenerative gas-burner is a result of experiments conducted simultaneously by Dr. C. W. Siemens, F.R.S., of London, and Herr F. Siemens, of Dresden, with a view to the attainment of increased illumination, greater economy in the consumption of gas, absolute steadiness of light, perfect ventilation, complete combustion, and the utilisation and disposal of the products of combustion. Each

of the experimenters arrived separately at the same conclusions, and the results of these conclusions may be seen in the burners which are now in use at the eastern extremity of Holborn, where they cast into comparative shadow the Edison electric light in the adjacent street.

The principle by which this improvement has been effected is mainly that of heating the air and gas previously to their union; and this is effected, in the regenerative burner, by causing the heat of the combustion, which is ordinarily wasted, to heat the gas and air which are next in rotation to be consumed.

The burner is shown in Fig. 196, and a section in Fig. 197, and it is composed of the following parts :—A, gas-chamber, supplying the gas-tubes, B; C, exit for the gas supplying the flame; D, air-chamber; E, regenerative heating chamber; F, suction-chimney leading to chimney G. When the burner is first lighted, gas in a cold state passes through the gas-chamber, A, and gas-tubes, B, to the point of ignition, C. Cold air enters the air-chamber D, and, before arriving at C, is equalised, and well distributed to the flame by means of a toothed circular collar. The flame burns around a tube of porcelain, H, and, turning over the top of it, descends into the interior of the burner, or regenerative heating-chamber E. This effect is produced by a continuous current, occasioned by the main chimney G, and the branch or suction-chimney F. The waste heat and products of the flame being thus collected in the regenerative heating-chamber E, the temperature of the latter is raised to about 900 C. The consequence is that the gas and air in the surrounding chambers, during the progress of their ascent from the bottom to the top of the burner, are raised to a similar temperature, thus increasing the illuminating power. Outside the burner is a jacket of thin metal, I, between which and the burner a current of cooler air ascends, to prevent the overheating of the burner, and also to add to the supply of air to the flame. On the top of this outer casing rests a cylinder of glass, K, which protects the flame from the action of the wind.

The illumination afforded by this burner has been tested by Mr. Keates, Mr. Hartley, and Mr. Heisch, with the result that it has been found to give, in its largest size, a greater amount of light than any other which has been constructed. The smaller sizes, however—those which would be applicable to rooms—are not equally advantageous, and scarcely, if at all, surpass the Silber argand in their performance, while their price is such as to be a serious impediment to their general adoption. The size No. 4, for example, which consumes ten cubic feet of gas per hour, gives fifty candle-light, and costs four guineas for the burner only. The pendant, which is essential to the performance of the burner, costs three guineas in its simplest form, and is of a shape which does not readily lend itself to ornamentation. For use in rooms, the suction chimney, F, in the figure, is duplicated by a dummy for the sake of symmetry, and the flame is covered by a conical glass shade, which reflects the light downwards. Even then it would seldom be necessary or desirable, in a room, to have the light of fifty candles concentrated in one spot; and most rooms would be better lighted by the distribution of lights of lesser individual power. For the present, therefore, we must conclude that the regenerative burner, although among the best in existence for street lighting, is hardly in competition with others for domestic uses; and its distinguished inventors must apply themselves to obtain an increase of power with small consumption and a diminution of cost before it can take rank as a household appliance, or can enter

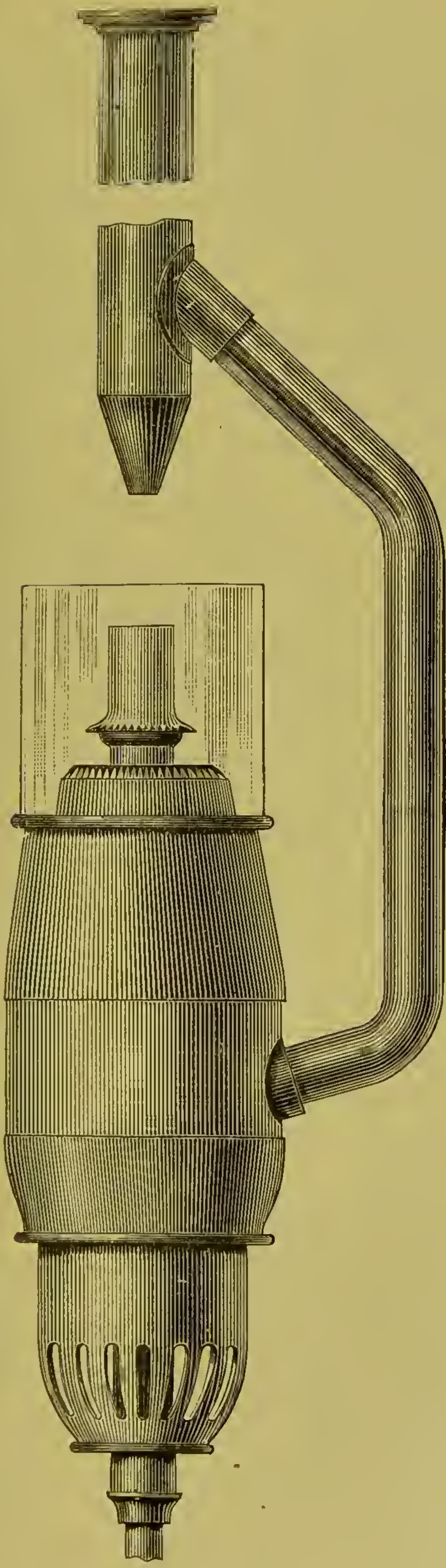


Fig. 196.

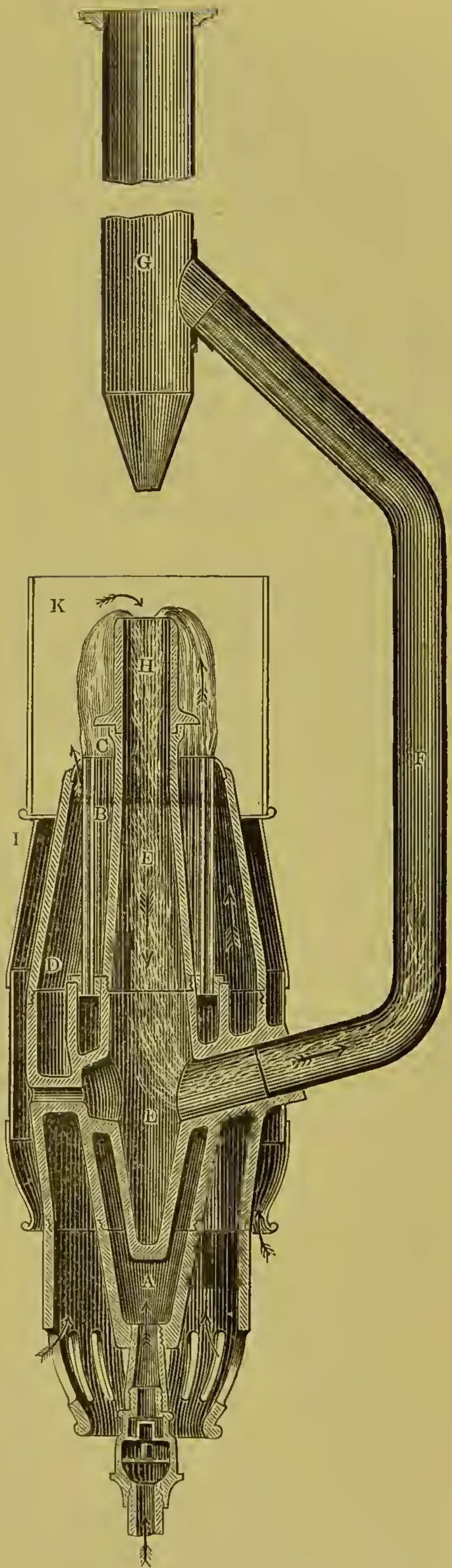


Fig. 197.

Elevation of Siemens' Gas-burner.

seriously into that competition between gas and electricity which must certainly be carried on for some time longer before it can be finally decided in favour of either. The influence of the regenerative burner in removing the products of combustion and the vitiated air of a room would doubtless be considerable; but these ends can be obtained perhaps equally well by simpler and less expensive means. The burner requires notice, but its domestic utility must belong rather to the future than to the present.

Another form of domestic light which effects something towards the removal of vitiated air is the so-called sun burner, which consists of a star of fish-tail jets placed beneath an enamelled basin, which both reflects light downwards and communicates with a pipe which carries away the heated air and the products of combustion. The gas sun-light answers admirably for large rooms in which no fine work is carried on, such as lecture-rooms, club smoking-rooms, and the like, but it is not well adapted for situations in which the eyes are employed over near and small objects.

A modification of the Siemens regenerative burner, from which great results are predicted, has recently been introduced by Mr. Grimston, who hopes to render it available for the small as well as for the large consumer. It may be described as an argand burner turned upside down, the flame curving round the margin of an inner cylinder, which contains the ring of gas tubes, and then ascending within an outer cylinder or chimney. The space between the two cylinders contains cross-tubes, which open into the external air by one extremity, and into the internal cylinder by the other, and which thus supply heated air to the flame. The latter is shut in below by a curved plate of glass, which hinges to the margin of the external cylinder, and the flame presents somewhat the shape of a convolvulus bloom turned downwards. In the experimental burners which alone have yet been constructed, the results obtained are said to have amounted to as much as sixty candle-light for a consumption of ten cubic feet per hour; and it is also said that smaller quantities of gas can be consumed in smaller burners with equal advantage. If this statement should be borne out by experience, the burner will be a great advance upon any now in the market. The appearance of the flame is pleasing, and the simple vertical pendant both lends itself to ventilation and admits of being rendered ornamental.

It has long been known that hydro-carbons brought into contact with oxygen at a sufficiently high temperature would burn without the production of flame; and Mr. Fletcher, of Warrington, has been conspicuous among those who have produced some remarkable heating results in this manner. The incandescent electric lamps have suggested to several inventors the idea that incandescence, for illuminating purposes, might be obtained by other than electric agencies, and notably by the so-called flameless combustion, with the result that two incandescent gas-lights are now, or soon will be, offered to the public. In the first of these, the incandescent gas lamp of M. Clamond, the incandescent material is a small basket of magnesia; while in the second, the lamp of Mr. Lewis, it is a thimble of platinum wire gauze. In both alike the principle is that when gas is burnt in such a manner as to heat a substance upon which the flame is thrown, this substance, as soon as it becomes sufficiently heated, will arrest the formation of flame, and at the same time, if sufficiently indestructible, will furnish a high degree of luminosity by its

incandescence. This is really the principle of the Drummond light; and the only novelty in its application is the attainment of a sufficiently high temperature by feeding common gas with atmospheric air delivered under pressure in lieu of the ordinary lime-light combination of oxygen and hydrogen. M. Clamond's basket is conical in shape, and is made of a sort of lacework of spun magnesia. The magnesia in powder is rendered plastic by a solution of acetate of magnesia, and is then worked like vermicelli into threads, of which a netted mesh is made. The baskets are very cheap, and are said to last for about forty hours of actual use, after which period they must be replaced, as the light which they furnish assumes a bluish tint. The renewal is easily effected.

In Lewis's incandescent burner the arrangement is practically the same. The basket or thimble of fine platinum wire gauze is placed on the summit of a double tube, the internal tube delivering air at high pressure, as from a blow-pipe jet, while the outer tube, surrounding the former, delivers gas at ordinary pressure. The combined air and gas are driven by the pressure through the gauze, and can be lighted from the outside of it. After burning for a few seconds, the gauze itself is raised to a white heat, the flame disappears, and the glowing gauze is alone visible as a source of brilliant luminosity.

It is claimed for the incandescent magnesia, and is certainly true of the incandescent platinum, that the light, although brilliant, is soft and pleasing in quality, and not irritating to the eyes; and in both cases the quantity of incandescent material is too small to become a source of undesirable elevation of the temperature of the room in which the light is used. In both lights an exceedingly high rate of illumination is said to be obtained for the quantity of gas consumed; and, inasmuch as this light is a result of the incandescence of the magnesia or of the platinum, and not of the incandescence of anything furnished by the gas itself, the quality of the latter, as regards illuminating power, ceases to be an element in the question. A gas suitable for heating purposes, poor in carbon, will be as good as, or even better than, any other; and such gas may be obtained at a cheaper rate than any which is itself capable of being used as an illuminant. In this way alone a great source of possible future saving is opened out.

On the other hand, a serious economical objection to the method is furnished by the necessity of supplying air under pressure in addition to gas—a necessity which seems to imply the laying down of an additional set of pipes for this purpose. In the Clamond burner, by an arrangement analogous to that of the Siemens and Grimston burners, the air is heated on its way to the flame; and it is claimed that the heating diminishes the degree of pressure which is required. If in this respect the Clamond possesses any advantage over the Lewis burner, it would obviously be only in maintenance from day to day; in the engine-power, for example, by which the air-supply was driven, and not in the cost of the original system of pipes through which it would pass. Against any saving thus effected may be put the fact that the Lewis or platinum burners are practically everlasting and indestructible, while those made of magnesia will require renewal almost as frequently as the wicks of an oil lamp. Of the relative merits of the two systems, and of the power of either to effect a sufficient saving to bring it into practical competition with gas burnt alone, it would as yet be premature to speak, and the ultimate decision must be arrived at under the guidance of an experience for which, as yet, no materials

have been afforded. The Clamond light has not at present been tried in this country, and the Lewis light exists only in an experimental condition. At the time of writing, arrangements are being made for its application to street lamps between the "Angel" at Islington and Clerkenwell Green; and it will, therefore, soon be visible to the public.

Another method of increasing the illumination from a gas-flame is to enrich the gas itself by the addition of further carbon elements. This may be effected by passing it through various fluid hydro-carbons, in vessels constructed for the purpose; but the best-known process is that accomplished by what is called the albo-carbon light. This light is obtained by burning gas which is enriched, while on its way to the burner, with vaporised naphthaline, and it not only, in round numbers, gives twice the ordinary illumination for half the amount of gas consumption, but the light is of purer and better colour than any other with which I am acquainted. The lighting of the Aquarium has been immensely improved in quality and in amount by its use, and this has been done at a saving of about £1,000 a year, on account of the corresponding diminution in the quantity of gas which is required.

Napthaline is a hydro-carbon which is solid at ordinary temperatures, so that, although it is formed in large quantities in the process of gas-manufacture, it is deposited in the larger tubes or in the reservoirs as the newly-made gas cools. When cold, it is a friable solid, of brownish-white colour, of a sort of semi-transparency, and of crystalline fracture. Until it was applied to the purpose of the albo-carbon light, it had no uses in the arts, and was a purely waste product, which gas-manufacturers were under the constant necessity of removing from their reservoirs and tubes, and which was useless and valueless when removed. It is readily volatilised, and its vapour possesses an extremely offensive odour.

In order to obtain the albo-carbon light, a piece of naphthaline is put into a reservoir connected with a gas-burner, and this reservoir is so arranged that, when it is warmed, the vaporised napthaline mingles with the gas, and is burned together with it. For single lights, gas-burners are made with strips of metal adjacent to the flame and extending to the reservoir, so that the heat communicated by them gradually volatilises the hydro-carbon. When the gas is lighted, the flame at first yielded is not distinguishable from that of an ordinary burner, but, as the warmth reaches the naphthaline, and the vapour is formed, the flame increases in size and brilliancy in a remarkable manner. When the naphthaline becomes exhausted, the flame returns to its original condition until a further supply is introduced. In large lights, as in gaseliers with several burners, the naphthaline is placed in a common central reservoir below them all, and under this reservoir there is a small jet, for the purpose of affording the heat necessary in order to maintain the supply of vapour. At the Aquarium, for example, the naphthaline reservoir and its tiny gas-jet may be seen under each gaselier, and an attendant, before the general lights are extinguished, goes round to turn out the small jets, so that the naphthaline is suffered to cool. If this were not done, it would be necessary to put out the gas by a tap at each individual burner, instead of by a tap common to many burners at once, because the closure of the latter would still permit the escape of naphthaline vapour, which would occasion an insupportable stench. For the same reason, it is necessary that the reservoir which contains the naphthaline should be perfectly closed, since any

opening in it would allow the stinking vapour to escape; and, for this reason, the albo-carbon light is scarcely applicable to private houses or small establishments. For a single burner, a fresh piece of naphthaline would require to be put into the reservoir about once a week, and few ordinary domestic servants could be trusted always to close the reservoir again with the necessary security. For this purpose a skilled workman would generally be required, and hence the light, notwithstanding its beauty and brilliancy, is only practically available where a competent person is always at hand to superintend it.

It will be sufficiently manifest from the foregoing that the introduction of the electric light has afforded an extraordinary stimulus to invention with regard to methods of illumination generally, and that it is also steadily tending to create a demand which such invention must supply. The practical lesson to be learnt from these facts is that builders or owners of houses should be prepared for any eventuality, and should arrange means for the easy conveyance or insertion of any systems of tubes or of wires which may ultimately appear to be the most advantageous. In the construction of new houses, and in the alteration of old ones, it will generally be possible to place matters in such a train that conductors for electricity, or tubes for air or for gas, or for both together, might be brought into the principal apartments without subsequent important disturbance.

CHAPTER XLV.

PETROLEUM AND OIL LAMPS.

Nature of Petroleum—Its Sources and Varieties—Importance of the Flashing-point, or Degree of Inflammability—Dangers of Petroleum—Improvements in Lamps—Colza Oil Lamps—Comparative Cost of Candles and Other Modes of Lighting—Impurities of Gas—Lamp Designs.

The illuminating agent next in importance to gas is undoubtedly petroleum, which, indeed, may be described as a gas of natural distillation. It consists of a mixture of hydro-carbons, some of them resembling marsh gas, others resembling olefiant gas, presenting among themselves many minute shades of chemical difference which there is nothing in their ultimate composition to explain, and which are referred to differences in the molecular arrangement of the carbon and hydrogen atoms which they contain. Nearly all are liquid at ordinary temperatures, some are very volatile, others fixed, others intermediate between the preceding, and some, of which "ozokerit" or earth-wax is an example, are found in a solid condition. They are all to be regarded as essentially vegetable oils, developed in the plants which formed the coal-measures, and separated when these coal-measures, in the course of geological changes, have been subjected to heat and pressure. In some instances, retained by strata impervious to them, and percolating through others of a more porous description, they have probably travelled long distances from the place of their production, and, like water under similar conditions, ultimately exude through fissures, or are permitted to reach the surface through wells sunk for the purpose.

Some of the native forms of petroleum were certainly known to the ancients; and Gibbon mentions that one of them—naphtha, or bituminous oil—is supposed, on slender evidence but with high probability, to have been the basis of the celebrated Greek fire. For a long period, however, and until quite recently, the only forms of petroleum used in the arts were artificial products, obtained by the destructive distillation of wood, peat, or bituminous minerals.

According to Payen,* the first impulse to the use of petroleum as an illuminating agent was given by Reichenbach, who, in 1830, prepared from beechwood tar both solid paraffin and an oil which could be burnt in suitably-constructed lamps. But, owing to the small amounts in which these products were obtainable from tar, or from the bituminous minerals then known, the various attempts made to bring them into practical application proved unsuccessful, until materials capable of yielding a larger amount of oily products were discovered. Among these, the principal were a remarkable bituminous mineral, occurring in the coal-measures at Boghead, in Scotland, and the tertiary coal or lignite occurring in several parts of Germany. Not long after the utilisation of these sources of liquid hydro-carbons had become an established branch of commerce, a new source of supply was furnished by the discovery of the vast deposits of petroleum in America; and hence, at the present time, the liquid hydro-carbons of what is called the paraffin series, which constitute

* "Industrial Chemistry," Paul's Translation.

native petroleum, as well as the products of distillation, are very largely employed as sources of light in lamps.

Petroleum occurs in many parts of the earth as a dark-coloured inflammable liquid, possessing a bituminous smell, and various degrees of density, from 0·7 to 1·1. Some kinds, which are thin and but slightly coloured, are known by the name of naphtha, while other kinds, which are viscid and almost black, are termed mineral tar. These different kinds of so-called mineral oil occur chiefly in North America, Persia, the Caucasus, Georgia, Burmah, the Carpathians, Italy, some parts of Germany, and Switzerland, as well as in France and England to some extent.

The petroleum of Pennsylvania is a dark brownish-coloured mobile liquid having a specific gravity varying from ·782 to ·820, and a peculiar greenish fluorescence. Some of the American petroleum has a greater density—for instance, that known as Mecca oil, which is a thick viscid liquid having a specific gravity of from ·860 to ·910, and some of the Californian petroleum has a specific gravity of ·927. The petroleum of Canada has a very offensive odour, owing to the presence of sulphuretted compounds which render its purification difficult.

In America, petroleum is obtained by boring deep wells, like artesian wells, until a deposit of oil is tapped, and then it either rises to the surface, and flows out in intermittent gushes, constituting what is termed a flowing well, or it has to be raised to the surface by means of a pump. The quantity obtained from these wells is sometimes very large. One of the great flowing wells at Enniskillen yielded as much as 600,000 gallons when first opened, but it was soon exhausted, and the greater number of wells yield only from 400 to 800 gallons daily, though some few have yielded as much as 4,000 gallons a day.

In Wallachia, petroleum is obtained from strata about thirty feet below the surface, and the wells are made by sinking square shafts lined with timber, like rude water-wells, and fitted with a windlass above, by means of which the petroleum, gradually oozing into the well from the adjoining strata, is from time to time taken out by buckets attached to a rope wound upon the windlass. Petroleum is also obtained in this way in Moldavia and Galicia along the entire range of the Carpathians. The best suited for refining has a specific gravity of about ·803, but some kinds are thick and much more dense, and they are used chiefly for greasing cart-wheels, &c.

Chemically speaking, the materials known as naphtha, petroleum, &c., are all very closely allied, inasmuch as they consist for the most part of homologous liquid and solid hydro-carbons, differing chiefly in density and volatility. The petroleum of America, as well as that of the Carpathians, consists chiefly of substances homologous with marsh gas, many of which have been isolated, and which range from gaseous forms to liquids having a boiling-point of over 260° C. The various kinds of petroleum also contain other liquid substances of still higher boiling-point, and of specific gravity sometimes exceeding ·900. They likewise contain in most instances solid hydro-carbons, varying in amount from 2 to 10 per cent. and upwards, together with pitchy and resinous substances.

The dark-coloured oily product obtained by the destructive distillation of wood, peat, coal, or other bituminous mineral, and commonly called tar, contains substances identical with those existing in petroleum, together with resinous and pitchy

substances, carbolic acid, creasote, nitrogenous bases, &c., the nature and relative proportion of these constituents varying with the kind of material submitted to distillation, and with the temperature at which the process is conducted. Distillation at a moderate heat, only just sufficient for decomposition, gives a larger amount of tar than is obtained at higher temperatures, which have the effect of decomposing the oily products to some extent, and of converting them into permanent gas, while at the same time furnishing tar of a very different character. Thus, in the manufacture of illuminating gas by distilling coal at a very high temperature, so as to obtain the largest possible amount of gas, the tar obtained is of a totally different nature from that which is produced at a lower heat, and is at the same time much smaller in quantity.

In the preparation of hydro-carbon oils for use in lamps, or for other purposes in the arts, the crude oil, whether obtained from wells or by destructive distillation, is submitted to ordinary distillation for the purpose of separating its intermediate from its heavier and lighter portions. In this way, the distilled oil is usually separated into four classes, namely :—

1. The light volatile oil, or spirit, known by the name of benzoline, and its congeners.

2. Oil suitable for burning in lamps.

3. Oil having a specific gravity above ·850, which is used for lubricating machinery, &c.

4. Oil containing a considerable quantity of solid paraffin, which crystallises when the oil is cooled, either at once or after some time.

The oil used for burning in lamps varies somewhat in colour, smell, specific gravity, and other physical characters, according to the source from which it has been derived, as well as to the care with which it has been prepared, and it is known under a great variety of designations, such as photogen, solar oil, kerosene, paraffin oil, besides other more fanciful names, indicative of a particular make rather than of any essential peculiarity in the oil.

The applicability of these products for burning in lamps is dependent upon the temperature at which they take fire, or give off inflammable vapour. The temperature at which the vapour given off by a sample of oil takes fire by contact with a flame, or the "flashing-point" of the oil, lies a few degrees lower than that at which the oil itself takes fire and continues to burn. In an oil of good quality, the flashing-point should be above any temperature which the oil will attain during use. According to Chandler, petroleum, during its consumption in glass lamps, with a surrounding temperature of 28° or 29° C., becomes heated after some hours to 30° or 33°, and with a surrounding temperature of 32° or $33\frac{1}{3}$°, it becomes heated to $33\frac{1}{2}$° or $36\frac{2}{3}$°. In lamps with metal vessels, the oil becomes heated to 54°; therefore such lamps are not to be recommended. According to the standard adopted in Great Britain and the United States, the flashing-point of oil of good quality should be above 37·6°. Most of the burning oil made from petroleum complies with this requirement, but when it is mixed with oil which boils at a lower temperature, the mixture will flash at a much lower temperature than the mean of the flashing-points of the ingredients, as is the case with inferior kinds of oil met with in commerce, and containing an admixture of naphtha. An oil flashing at 45° C. would, according to Chandler, by the addition of 1 per cent. of naphtha, have

its flashing-point lowered to 39° ; by 5 per cent. of naphtha, it would be lowered to 28° ; and by 20 per cent., to 4°.

In this country, petroleum is defined by Act of Parliament as being any oil which gives off an inflammable vapour at a temperature of less than 37·6°, but the method at present in use for determining this point is very imperfect, and gives results which are untrustworthy.

The oil prepared from native petroleum is almost colourless, but has a slight bluish fluorescence. It has a specific gravity of about ·810, and when of good quality only a slight and rather aromatic odour. It is now entirely manufactured in America, and is exported thence in very large quantities.

The oil obtained from bituminous shale or from coal is generally of higher specific gravity ; it has more colour, and a less agreeable smell.

The oil obtained from brown coal tar, and known by the name of solar oil, is almost colourless, with a slight yellowish-green or blue fluorescence. Its specific gravity is from ·825 to ·835. The lighter and more volatile portion of the oil obtained from the same source, and called photogen, has a specific gravity of from ·810 to ·825. The temperature at which either of these kinds of oil takes fire varies with the specific gravity, as follows :—

	Sp. Grav.	Temp. (C.).
Photogen	·800	33·1°
,,	·805	37·1°
,,	·808	45·1°
Solar oil	·824	60·0°
,,	·827	68·1°
,,	·830	76·0°
,,	·835	77·0°
,,	·845	92·0°

It may, therefore, be laid down as a general principle that all the valuable properties of petroleum as an illuminant are afforded by the ordinary oil of commerce, which is sold for the purpose of burning in lamps, and which is always to be procured at the market price of the day, a price which fluctuates subject to the operations of "oil-rings" in America and elsewhere. Such oil is always less expensive than those which are sold by dealers under various special unmeaning names, and which, as a rule, have nothing but their higher price to recommend them. As regards security, that is sufficiently provided for, or at least is as much provided for as circumstances will permit, by the requirements of the Act of Parliament, which prohibits any petroleum oil from being sold by retail which has its flashing-point below a temperature of 100° Fahrenheit.

The risks incidental to the use of petroleum oil are—first, explosions; secondly, fires.

The oil itself, as has already been explained, is little more than a gaseous hydro-carbon condensed into a liquid form, and capable of being brought into the state of gas or vapour by a certain elevation of temperature. The resulting gas or vapour precisely resembles coal gas in this, that if mixed with a certain proportion of atmospheric air, it will explode when brought into contact with flame, or with incandescent material of any kind. If we have a lamp, partially filled with petroleum oil, and containing air above the level of the petroleum, and if into this air, in consequence of the oil being of too volatile a character, or in consequence

of the vessel being unduly heated, the vapour of petroleum rises, and mixes with the air in a given proportion, and if then, by any carelessness, this mixture of air and vapour is brought into contact with incandescent material, an explosion will be produced. The effect of such an explosion will probably be to shatter the con taining vessel, and to allow the heated oil to escape, after, in all probability, it has already been ignited by the flash. The burning oil has often inflicted serious injuries upon persons in the room, and in some instances has occasioned fires which have only with difficulty been extinguished.

When petroleum was first taken into common domestic use, explosions of the kind just described were by no means infrequent, and served to bring the oil into not altogether unmerited disrepute. They were mainly due to two sets of circumstances—first, to much of the oil then sold having too low a flashing-point, so that the upper part of the containing vessel was almost always full of dangerous vapour; next, to such a construction of the lamps as rendered it easy to turn down a glowing wick into this vapour in careless attempts to extinguish them. The Petroleum Act, by prescribing a safe flashing-point, deprived the oil of ordinary commerce of its dangerous volatility; and, at the same time, lamps of improved construction were so made that they could be extinguished, even with more inflammable oil, without risk of bringing glowing cotton into the receptacle. By the combination of these two influences the explosion of petroleum lamps is now almost unknown.

The danger of petroleum as a source of fires does not depend so much upon the liability to explosion, just noticed, as upon the tendency to produce a highly-inflammable place where the lamps are habitually trimmed. Petroleum is an exceedingly subtle fluid, with a capacity for evading restraint which is all its own. It will ascend the inside of the oil-vessel, will make its way through the junction of the burner at the top, and will spread itself out in a thin film over the external surface, of any lamp in which it is used. If a drop falls upon wood, it will creep into its substance to a considerable depth. If a small room or closet is constantly used as a place for trimming and preparing petroleum lamps, the small unavoidable spillings of each day will in time saturate the floor and the table with oil, and will render them prompt to catch fire from any fallen match or other bit of smouldering material. A place thus prepared will not only catch fire, but will burn with great intensity, developing a degree of heat which provides for the rapid extension of the flames. On this account, petroleum is dangerous on board ship; where it would probably be better that its use should be prohibited altogether. It is also dangerous, though in less degree, at railway stations, especially such as are constructed chiefly of wood. In such situations, any closet used as a lamp-room should be lined with zinc or other metal; but, in ordinary domestic use, the danger may be looked upon as non-existent if ordinary care is used. The lamps should be trimmed upon a metal tray, placed on the table of a room used for other purposes, and the work should be done by daylight. The tray itself may be wiped before it is put away, and then no specially inflammable place can by any possibility be created.

In domestic use, a common cause of leakage is the accidental overfilling of the lamps; and this may be completely avoided by a simple and ingenious filling-can, invented and patented by Mr. Silber, which is shown in Fig. 198. The curved part

of its spout contains two tubes, the upper one opening at the top of the interior, the lower one at the bottom, the former serving for the entrance of air, the latter for the exit of oil. The can itself is filled by unscrewing the plug in the centre of its sunken top, which is then to be screwed down again. The spout is to be placed about one inch inside the lamp reservoir, and the oil poured into the latter in the ordinary way. As soon as the oil in the reservoir rises to the level of the upper tube of the spout, it closes the latter to the entrance of air, and no more oil can escape. The household stock of oil may be kept in a metallic drum holding about five gallons, from which it can be drawn out into the filling-can by a common tap.

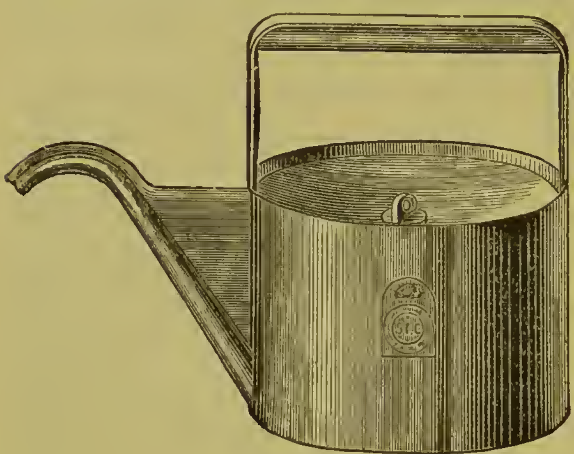


Fig. 198.—Filling Can.

We come next to a class of illuminants in which hydrogen and carbon are combined with oxygen in various proportions, and which includes the oils and fats directly derived from the animal and vegetable kingdoms. Among these, the most important oil, and that which comes next to petroleum, is the so-called "colza," which is obtained by expression from the seeds of several varieties of the genus *brassica*, called comprehensively "rape-seed," but with which other vegetable oils are mixed. The vegetable oils, as first expressed, contain a quantity of mucus and other albuminous matter, which interferes with their use in lamps by clogging the wicks with charred material, and which is removed, more or less completely, by various chemical processes which it is not necessary here to describe. Colza oil is less volatile than ordinary petroleum oil, less inflammable, more viscid, and requires burners of different construction. It is also considerably more expensive; but its light is generally of a very agreeable quality, it gives off no injurious vapours, and its employment is entirely free from risk. On account of these advantages, coupled with its lower price, it has entirely superseded sperm oil, procured from the cachalot, or sperm whale, which was once greatly prized as a means of domestic illumination of a superior kind.

The lamps in which petroleum oil was burned when it was first introduced into ordinary consumption were of a very simple and inexpensive character, and the oil itself was for a long time regarded as an inferior source of light, suitable for cottages, or for the rooms occupied by domestics, but not adapted for the living-rooms or reception-rooms of the wealthier classes. The common petroleum lamp had a single flat wick, of a width varying with the size of the lamp, and this wick was scarcely at all elevated above the level of its containing-tube. The flame itself found issue through a slit in a sort of dome or cap, which covered the wick-tube, and served to regulate the air-supply in the manner and degree suited to the requirements of the fuel. The lamps were apt to exude petroleum, and in this way to produce more or less smell in the rooms where they were used; and the smell of extinguishing them was especially offensive. The lamps themselves were not ornamental, the containing-vessels being usually blown of cheap glass,

with moulded patterns, and the metal-work of the burners being of the thinnest and most trumpery description.

The first step in advance of this state of things was made by Messrs. Hinks, of Birmingham, who greatly improved the illumination afforded by petroleum by the construction of their "duplex" burner, in which the single flat wick was replaced by two parallel ones. The light given by these lamps was so much better than any previously obtained, that it beeame worth while to improve the manufacture of the oil vessels and burners, so as to produce table lamps of an ornamental character; and this improvement coincided with a general diminution of the fear of petroleum explosions which had formerly been not unreasonably entertained. These duplex lamps found admission into many good houses, and paved the way for the improvements which have since been made.

When Mr. Silber first began to devote his attention to the best methods of obtaining artificial light, his experiments were chiefly or entirely made with petroleum; and he succeeded after a time in obtaining two desiderata, the first being a much-improved illumination, the second a convenient way of supplying the fuel to the lamps. His original petroleum burner was an argand with an internal tube, constructed upon the same principles which he has since applied so successfully to the improvement of the argand gas-burner, and it was fed by oil laid on through tubes from a reservoir, precisely after the manner of gas. The lamps were attached to wall brackets, and behind each bracket was a small reservoir, whieh was fed from the general one to the extent permitted by a stopcock governed by a little float, which kept the oil always at the same level. The general reservoir, which fed the small ones, was at the top of the house, and had a tube running down to communicate with the sewer, so that, in case of fire on the premises, the large reservoir could be at once emptied into the sewer by turning a stopcock on this tube, and all risk could in this way be obviated. Mr. Silber fitted up a portion of his warehouse in Wood Street with oil lamps thus supplied; and, when any one of the lamps was extinguished, inasmuch as its consumption of oil was stopped, the float-governed stopcock prevented the admission of any more to the small reservoir, and prevented waste. The arrangement was even more simple than that commonly adopted for gas, because, in order to prevent the escape of the fuel, it was only necessary to put out the light, not even to turn any tap. One three-branch chandelier in Wood Street was so constructed as to burn petroleum with one branch, colza with another, and gas with the third. A full description of the arrangement, with illustrative sectional drawings, was given in the Journal of the Society of Arts, with a paper read by Mr. Silber on the 21st of December, 1870; and in this paper he mentioned that the inspectors of the principal fire offices had visited his place of business, and had pronounced the method of petroleum-supply to be in every respect as safe as the use of gas.

Mr. Silber had to overcome unexpected difficulties in the method of lighting referred to, on account of the tendency of petroleum to exude through or otherwise affect many metallic and other substances. It could not be conveyed through ordinary gaspipe, but it was at last found that pipes of pure tin might be employed. There was a difficulty of the same kind in obtaining a suitable material for the floats to govern the stopcocks, but this was overcome by the use of thin porcelain. At present, the plan possesses no more than a theoretical interest, inasmuch as

Mr. Silber is not disposed either to work the patents covering it, or to allow them to be worked by others. He permits and recommends the arrangement in hothouses, where the self-acting floats will keep a petroleum lamp or heating apparatus at a uniform level from night to morning, without any attendance being required.

Mr. Silber's argand petroleum burners were a considerable advance upon any which had preceded them; but, after a time, in consequence of the demand for flat-flame burners, he extended his investigations to the improvement of these also. The flat-flame burners manufactured by him are of two chief kinds, called respectively the "Miratus" and the "Miratus Duplex."

The Silber petroleum argand burner is, as already stated, almost identical, as regards air-supply, with the Silber argand gas-burner, which, indeed, was modelled upon it, and owes its existence to the experiments made in the first instance with petroleum. In certain details of construction, of course, the two burners differ, in accordance with the physical differences of the fuels which they are respectively intended to consume.

By means of the regulation of the air-supply, the combustion is so far perfected that less petroleum oil, light for light, is consumed by this burner than by any other. As compared with the well-known "Kosmos" burner, for example, which is also an argand, it gives from 3·5 to 4 more candles of illumination for the same consumption of oil. It also differs from the "Kosmos" burner in the arrangement of its air-supply, the Kosmos having only one current of air within the flame. The latest form of the Silber argand has an additional improvement in the method of introducing a new wick, which is done from the top of the burner without removing it from the lamp.

The Silber "Miratus" is intended to meet the popular demand for a flat-flame single burner. It has a single wick of $1\frac{5}{8}$ inch in width, and is so constructed that, according to experiments made by the late Professor Valentin, of the Royal College of Chemistry, it affords the same amount of light as the original Duplex, at a somewhat less expenditure of oil.

The Miratus Duplex burner has two air restrictors of fine wire gauze within the body, or, as it is technically called, the basket, of the burner; the upper one being arched, and the lower of inverted conoidal form. This arrangement not only renders the lamp less liable to smoke when carried about, but also very much facilitates trimming, since the wicks only require to be cut off straight, or level with the tops of their containing tubes. It has been found by experiment that with a single horizontal air-restrictor only twenty-five candle-light can be obtained from this burner, but the double gauze improves the combustion and increases the illuminating power.

The extinguisher of the Miratus Duplex consists of two tubes, external to the wick-tubes and surrounding them, which are raised above the level of the flame by a simple lever, and which can be depressed again by its means. By this arrangement, the brilliancy of the illumination can be diminished at pleasure, by the simple expedient of somewhat raising the extinguisher tubes; and, when the tubes are lowered, the flame will recover its former brightness. In a quite recent form of the Miratus a channel is provided through which a match can be introduced from without, and fixed in such a position that it may be ignited by raising the

extinguisher lever. By this contrivance the lamp can be lighted without removing either the globe or the chimney-glass, and the match can be withdrawn as soon as it has fulfilled its purpose. In Hinks's Duplex, when the lever is depressed, the flame is extinguished by two little metallic shutters, which are thrown over it by the action of released springs.

An especial advantage of the Miratus Duplex is that it affords an equable light for six hours or more, while in most other lamps the light will diminish in the same time from twenty-five to fifteen candles. This result is obtained by attaching to the bottom of the burner, between the two wicks which are being consumed, two additional ones of highly porous material, which reinforce the capillary attraction of the others, and maintain the adequacy of the oil-supply as the level of the fluid sinks.

The general result of a comparison between the Silber and other flat-flame burners appears to be in favour of the former on all grounds, the difference between it and the best of them not being great, but sufficient to justify a preference. The Silber petroleum argand is, perhaps, still better, but it is not so easily managed by the average servant.

For burning colza oil, the common moderator lamp has been widely used, and also the so-called "Queen's Reading-lamp," both of which have common argand burners. The common Queen's reading-lamp is almost too well known to need description. It is chiefly manufactured by Stobwasser of Berlin, and is sold by English retailers at prices which are much governed by the locality of the shop. It is made in brass or German silver, and the latter is often electro-plated. It is furnished with a semicircular glass shade, either of white opal glass or of green glass with a white lining, the former being the best when general illumination of the room is to be combined with table lighting, the latter for table lighting only. The German lamps are fitted with common argand burners, which afford a light about equal to that of twelve candles; and this amount can be nearly doubled by the use of Silber burners instead. The common burners will consume only colza oil, while the Silber burners for petroleum can be obtained if desired; but the difficulties of overcoming petroleum leakage in lamps of this class are almost insuperable, and colza is, as a rule, much to be preferred for them. To these lamps Mr. Silber has applied his argand burner with the same success as in other directions. Except in points of detail, it does not differ from the Silber argand for gas or for petroleum; its peculiarity being the inner tube, which forms an inner central air-current, and the metal cone which directs the three air-currents, the one without and the two within the flame, to those parts of it where they will exert the most favourable influence upon the combustive process. The light thus obtained is greatly in excess of that which is afforded by the common burner, but the particulars of the various kinds of illumination will be most fitly dealt with in instituting a comparison between them all.

In order to do this, it will be well to commence by a reference to candles, the favourite illuminating agents of the early part of the present century, and which for some purposes, still hold their ground in public favour. The best candles are the so-called "sperm," which are used for testing the quality of gas under various Acts of Parliament, and each of these candles consumes an average of 120 grains of fuel per hour. The average cost of sperm candles is 2*s.* 6*d.* for a pound weighing 7,000 grains.

Let it be supposed, as a basis of calculation, that a uniform light of twenty candles is required for a period of 100 hours. The cost of obtaining it by different forms of fuel would be as follows :—

Twenty sperm candles would burn 2,400 grains per hour, or a total of 240,000 grains. This amount, divided by 7,000, the number of grains in a pound, gives 34·28 lbs., or a cost of £4 5*s.* 9*d.* Ozokerit candles, which cost a shilling a pound, would yield the same result for £1 14*s.* 3*d.*

Colza oil, burned in moderator lamps with Mr. Silber's burner, is consumed, according to the experiments of Professor Valentin, at the rate of 49 grains for each candle-light per hour. This would give, for twenty candles for 100 hours, a total consumption of 98,000 grains, or an expense, reckoning 9 lbs. to the gallon and 3*s.* 6*d.* per gallon as the price, of 5*s.* 5*d.* Ordinary moderators consume 65 grains per candle-light per hour; and with them the cost would therefore be 7*s.* 2*d.* for the same result.

Petroleum oil, also, when burned in Silber burners, is consumed at the rate of 48 grains per hour for each candle-light, so that 84,000 grains would be required for the twenty candles for 100 hours. This, at 1*s.* 4*d.* per gallon of eight pounds, would cost 2*s.* As between the solid and liquid fuels, therefore, candles are a very costly luxury when compared with colza oil, and this again is two and a half times the price of petroleum.

The means of extending the comparison to gas are afforded by the Report which has already been so largely quoted. Gas in London costs 3*s.* 4*d.* per thousand cubic feet, and we have seen that this gas, when burned in the tubular argand of Mr. Silber, or in the argand burner of Mr. Sugg, which is nearly as good, affords a light equal to that of 18·6 candles for a consumption of 5 cubic feet per hour. It follows that the light of twenty candles for 100 hours would be afforded by a consumption of 537 cubic feet, which would cost 1*s.* 9½*d.* The best of the flat-flame burners gave 16·2 candle-light for the consumption of 5 cubic feet of gas; so that for twenty candles for 100 hours the consumption would be 617 cubic feet, at a cost of 2*s.* 0¾*d.* Against the economy of argand burners, whether for gas or for petroleum, it has to be considered that their use is attended by expenses incidental to the breakage of chimney-glasses, not only from accident or carelessness but also from defective annealing. I have seen the chimney of an argand gas-burner crack in the middle of the day, when nobody was touching it, merely from molecular changes incidental to variations in the temperature or moisture of the atmosphere. It would be very difficult, if not impossible, to reduce such accidents to anything which could be called an average.

Such being the facts with regard to relative cost, it is next necessary to inquire into other features of each fuel which may properly be made the subjects of comparative statement. It has already been mentioned that, soon after gas came into general use, it had to be abandoned in many places, such as clubs and public libraries, on account of its injurious effects upon books, pictures, and furniture; and candles were again taken into favour and are still employed in some of such places. In the Paris Opera House, according to the *Times* of October 10, 1882, the introduction of Swan electric lamps has been most prominent in the *foyer*, "the extremely elaborate decorations of which have been entirely spoilt by the ruthless effects of gas." If we examine the gas-burners which were abandoned many years ago, and ascertain what was their

illuminating power, we shall find that in order to afford twenty candle-light for an hour they had to consume, or waste, at least 12·5 cubic feet of gas, or more than 7 cubic feet in excess of the quantity now required, with the best argands, to produce the same effect. It is therefore obvious that a large amount of gas was either wholly wasted, or at best liberated into the air of rooms in a partially-consumed condition, which substituted various noxious compounds for the carbonic acid and water which are the results of finished combustion. It was no doubt on account of these noxious compounds, rather than on account of any results necessary to its use, that gas fell into comparative disrepute; and it will probably be found that better methods of burning will at least produce a great diminution of such disadvantages, even if they do not entirely obviate them.

It must not be forgotten that gas, when first introduced, was at once used in such quantities as to afford a much larger amount of light than had ever been expected from wax or sperm candles; and that, if wax candles had been used in sufficient quantities to produce as much light as was expected from gas, the deleterious effects of their combustion would have been very appreciable. We have seen that 120 grains of sperm are required to afford the same amount of light which is given by 42 grains of petroleum; and it is clear from this that something like 78 grains of the solid fuel must be dissipated every hour, in a more or less unconsumed condition, through the air of the apartment. Persons whose respiratory organs are sensitive rapidly discover the presence of too many lighted candles in a room (too many, that is, either for the cubic space or for the quantity of air-supply), by reason of a peculiar stuffy sensation which is produced by inhaling particles of unconsumed and minutely-divided carbon; but it has to be remembered that, in the case of gas, there will not only be this source of discomfort, but also the presence of sulphur compounds from which candles are free. It is the sulphur, in all probability, which confers upon gas its power of injuring inanimate substances; and it is hence that gas, notwithstanding its convenience and economy, continues to be objectionable for rooms which contain books, paintings, sculpture, or valuable furniture of any kind. Science has done much to diminish the objections to its use by means of improved burners, but there are as yet no facts to show what degree of success has been obtained. The danger has been diminished, certainly in some degree, and perhaps in a very great degree if due regard be had to the relative proportion between the amount of illumination and the cubic space of the room, as well as to the arrangements for renewal of the contained air by ventilation; but it is likely to be long before the proprietors of perishable articles of value will be content to expose them to even the smallest possible injury which gas-lights may effect. I am acquainted with a country house in which a drawing-room containing many rare, choice, and beautiful things is lighted by gas in a manner which allows no injury to be done, but which could only be accomplished where, as in the instance in question, there is no other room above. In this case the upper portion of the walls is curved, in such a manner that the ceiling is somewhat smaller than the floor-space, and this ceiling is of ground glass. The gas-lights are placed above the ground glass ceiling, in a chamber of which it forms the floor, and a flood of soft light is diffused downwards, without heat, without smell, without contamination of the air, and without the possibility of injury either to the health of living beings or to the perfection of works of art.

The dangers which were once incidental to the use of petroleum may now be regarded as wholly belonging to the past, and have been sufficiently referred to in the context, unless it be to point out that a petroleum lamp may at any time be rendered offensive, or even dangerous, by a servant who does not understand its management. When properly trimmed and properly lighted (and these conditions are very simple and easy of fulfilment), the lamp gives a sustained and brilliant light without smell; but a small departure from the proper positions of the wicks will occasion a very disagreeable and penetrating odour, and the accidental omission to light one of the wicks of a duplex burner has before now occasioned an explosion. It has been already said that petroleum is almost identical in composition with gas, from which it differs chiefly in retaining the fluid form at ordinary temperatures; and it follows that it is scarcely more to be recommended than gas itself for the lighting of rooms in which very valuable property is contained.

It remains to consider whether colza oil is a more desirable illuminating agent than any of the foregoing; and, if we take into consideration that, with the Silber argand burner, its waste is brought within very narrow limits, there can be little question that it offers advantages for all places where it is of paramount importance to avoid the suspicion or possibility of risk to life or to property. The figures already given show that colza is an expensive lamp-fuel as compared with petroleum; and it may be added that the lamps in which it can be consumed with advantage are necessarily of a more expensive construction, and that they also require more time and care in trimming, and in keeping them clean and in good order. Notwithstanding this, when it is considered that no danger can arise in connection with their use, and that the light which they afford is as pure and brilliant as can be desired, there is little more to be said than that they are the best of all lamps when expense is a secondary consideration, and when purity of atmosphere is of the first importance. Colza oil differs from petroleum in containing oxygen as one of its ingredients, so that it may to some extent be said to carry with it its own supporter of combustion, and to be somewhat less dependent than any other oil upon the quantity of atmospheric air which gains access to its flame.

There is a lamp of recent introduction which is not without some merit, and which, therefore, deserves brief notice. It is manufactured in America, from a design which was originally French, and is sold as the "Empress" lamp. It has a flat wick, and burns petroleum without a chimney, the regulation of the air-supply being effected by the rapid revolution of a fan, which is situated beneath the flame, and is worked by clockwork. The Empress lamp gives a flame of very pure white colour, and the vase, which, in all the specimens I have seen, is nickel-plated, is of good design. Its faults are a large consumption of fuel for light given, and a rapid decrease in the amount of light after the first hour; while the whirr of the fan and its clockwork are very objectionable to sensitive people. Moreover, if the clockwork happens to run down while the lamp is still burning, the flame immediately begins to smoke; and, if this chanced to occur when there was nobody in the room, the result would be eminently disagreeable. The lamp starts with an illumination equal to twelve candles; and this, after an hour, soon falls to about eight, at which point it remains nearly stationary until the clockwork stops or the oil is consumed. The clockwork is said to run for thirty hours when fully wound, but this has scarcely

been true of the lamps which I have seen in action, and is, indeed, a much longer time than could be either necessary or desirable. The flame is usually covered by some kind of glass shade, of a shape adapted to the tastes or wants of the purchaser; and it may be said of the lamp, in a general way, that it may be used when only moderate illumination is necessary, and when the noise it not objected to. This noise may, of course, be very much damped by placing the lamp upon a thick tablecloth of some woollen material. With a graceful shade, the lamp is a pleasing object; but against this must be set the largeness of its consumption of oil, which is not only wasteful, but also a source of contamination to the atmosphere.

Of lamps as articles of decoration, this treatise is hardly the place to speak, and it is sufficient to say that the burners already mentioned can be obtained attached to vases of all materials, and of every degree of beauty and ugliness. Silver or plated metal, real or imitation bronze, glass, and china, form the most ordinary materials; and one lamp-dealer appears to enjoy a monopoly of the sale of lamps attached to, or supported by, stuffed birds or animals. It will be conceded, I presume, by the majority of people, that, as birds and beasts do not support lamps when living, it is questionable taste to make them do so when dead; and a polar bear, holding a lamp in one paw and hugging a turkey with the other, has always appeared to me to be a triumph of grotesque unfitness and ugliness. This sort of thing has, nevertheless, its attractions for some people; and I know of no right on the part of others to quarrel with them. Whether any given taste be good or bad, it is at least certain that in London it can be indulged to the utmost.

CHAPTER XLVI.

GENERAL CONCLUSIONS.

Gas not advisable for Houses—Evils of a Small Flame in Bed-rooms—Oil Lamps for Reception-rooms—Physiological Evils of Hanging Lamps—Coloured Light—Reading and Study Lamps—Methods of Diminishing the Heat of Lamps.

On a review of the whole subject it would seem that, although the many conveniences attendant upon the use of gas will always, or at least until the electric light is more generally available, render it the best means of illumination for shops, factories, warehouses, theatres, and public buildings and places generally, yet that for private houses its use may with advantage be limited to the basement, offices, and staircases. Its introduction into bed-rooms is very undesirable from a sanitary point of view, since it consumes much oxygen, and therefore, if habitually lighted by the servants before the members of the family retire to rest, it vitiates the atmosphere of the bed-rooms before the time comes when that atmosphere is to be called upon, generally with very imperfect arrangements for its renewal, to supply the respiratory wants of the sleepers. It is a common error to suppose that the extent of this vitiation is so small as to be of no moment, when the gas flame itself is very small, turned down so low as to be just visible, and left thus as a mere matter of convenience, in order that it may be turned up without the trouble of lighting when it is required. A small flame does not, of course, consume so much oxygen as a large one, neither does it produce so much carbonic acid, nor so much elevation of temperature. On the other hand, the imperfect combustion which is an incident of a small flame means that, instead of carbonic acid and water, the air becomes loaded with partially-burnt hydro-carbons and other noxious products; and any one with a fine sense of smell, and a sensitive respiratory surface, who goes into a room which has been shut up with a small gas-flame left burning in it, will instantly perceive the very objectionable character which has been conferred upon the contained air. Of course, it is still worse when a bed-room gas-burner, turned down to its lowest point, is made to do duty for a night-light, and to continue its process of air-poisoning until the morning.

For bed-rooms, generally speaking, there can be no doubt that candles are the best illuminants, and a pair of candles on the mantelpiece, and another pair on the dressing-table, with a box of safety matches in a known position, where they can be found in a moment, leave nothing to be desired in the way of convenience. When more light is required, as when a lady is dressing for the evening, a lamp in any convenient position, and the addition of candles to the sconces attached to the dressing-mirrors, will be sufficient for all purposes. For the night, a candle and safety matches upon a bedside table, which will render it possible to obtain a light in a moment if it is required, are much to be preferred to the use of a night-light. The latter not only, in some degree, vitiates the air, but it also takes away what, for many people, is an essential condition of the deepest and most refreshing sleep, namely, darkness. It is well to accustom children to sleep in the dark from their

earliest years, before the foolish fears and fancies so often connected with it have had time to be put into their heads by mischievous or superstitious people.

Besides the places already enumerated, the only rooms in which I would have gas in an ordinary dwelling-house are those in which, on account of some pursuit or occupation carried on in them, light is liable to be required unexpectedly and at odd times. For example, I have gas in my own consulting-room, because there, on any dark morning, I may desire to light up the objects which are used as tests for the acuteness of vision, and to vary the amount of light with precise reference to the degree of the external deficiency.

In the lighting of reception-rooms, or rooms for general family use, oil lamps are by far the most desirable means of any which are now available; and, as already stated, colza lamps should be preferred to petroleum for rooms of very choice contents, or in which cost is a secondary consideration. The absolute amount of light employed, and the manner of its distribution, must vary, of course, with the nature of the occasion and with the uses to which the room is habitually applied; but several conditions at once suggest themselves. There is the lighting for the reception of company, as for an evening entertainment, the lighting of a room for a smaller circle, assembled to talk, or to hear music, or at least not to follow any definite occupation, the lighting of a room for dinner, and the lighting for that daily use in which some members of a family may desire to read, to write, or otherwise to apply their eyes to near objects, while others are content to be unemployed. There is also the lighting of a room for the purposes of study, whether it be the library of an adult or, what is still more important, the room in which children prepare their lessons by the aid of small and badly-printed books.

In lighting up a room for an evening entertainment, as a dance or a conversazione, the objects to be secured are that the light should be sufficient to exhibit the beauties of women, of dress, of jewels, and of any pictures or other attractive objects upon the tables or walls; while at the same time it should not occasion distress by being excessive in amount, or by the direction of its rays. It should also be of the purest colour, the nearest to sunlight that is attainable.

For the fulfilment of these requirements, in any establishment of sufficient size, I should make an exception to my objection to gas, and should recommend its use in the form of the albo-carbon light, already described as being employed at the Westminster Aquarium.

For evening entertainments in ordinary dwelling-houses, the chief question is whether the light should be furnished by lamps pendent from the ceiling, or attached to the walls, or by both these methods combined. With regard to the amount of illumination, it is not possible to frame any rule about the proportion which this should bear to cubic space, because so much will depend upon the texture and colour of the wall-surfaces and of the contents of the apartment. A room of generally dark tone would bear, or even require, twice as much light as one in which the opposite condition prevailed.

Where the height of the room is sufficient, the best method of lighting is by lamps suspended from the ceiling, and these may be either single or combined in chandeliers. The two essential conditions of success are that they should be high enough to be quite above the heads of even the tallest dancers, and that they should burn, without marked diminution of light, necessity for trimming, or risk of smell,

for a time longer than any during which their illumination could possibly be required. The last-mentioned condition would be fulfilled by either colza or petroleum lamps, with reservoirs of ordinary size and Silber burners. It is of course necessary to see that the reservoirs are properly filled at the beginning of the evening, since nothing would be a greater nuisance than to have lamps removed during a dance for the purpose of refilling them.

The advantage of the central illumination afforded by suspended lamps is that it so well exhibits pictures upon the walls; but, where there are no pictures of any special attraction, or where the central illumination is insufficient, this may be reinforced by wall lights. For these, candles should never be used; since, when a room becomes much heated, and the wax or stearine of which they are composed much softened, it melts in excess of the combustion, and is apt to drop upon guests who are standing beneath. This trouble may be entirely avoided by the use of lamps, and lamps are now made fitted to wall sconces, the latter being of every kind, from the plainest and simplest to the most elaborate and the most ornamental. Silver, brass, glass mirrors framed in velvet, and china, of all degrees of costliness, furnish the materials of sconces such as may now be seen wherever such things are exhibited. On the whole, I think the preference should be given to glass mirrors as the main element in sconces, on account of their effect in distributing the illumination more widely than other materials; and the framing, whether in velvet, in coloured glass, or in china, should be governed by the other decorations with which they are required to harmonise, and by the general character of the room in which they are hung.

The number of suspended lamps must be regulated, of course, mainly by the size and shape of the room, with a view to the attainment of symmetry and harmony of effect; and, when as many have been placed as will fulfil this indication, they must be lighted with a view to ascertain the sufficiency of the illumination. Taking my own drawing-room as an illustration, I have four suspended lamps, one hanging from the centre of the ceiling, one in each of three divisions of a bow-window. These four are sufficient for a conversation light, but would not be enough for dancing, or for the comfortable pursuit of any occupation, such as reading, embroidery, or even card-playing, the light being to some extent wasted by the absorption effected by dark walls and dark furniture. No more hanging lamps could be introduced without producing an effect of over-crowding, so that any additional light required for other purposes must be supplied in other ways. Upright or vase lamps upon tables, or upon special stands made to carry them, candles, and lamp-sconces for the walls, are the chief resources. The latter would only be used for dancing; the candles would be the best for card-tables and music-stands; and the upright lamps, suitably shaded, for most other occupations in which the occupants of a drawing-room are likely to be engaged.

Whenever suspended lamps are employed, either to burn gas or oil, it is necessary to consider carefully the ventilation of the apartment. The air which is vitiated by respiration and warmed by the human lungs has a tendency to rise: for, although its weight is increased by the addition of carbonic acid gas, the increase is more than counterbalanced by the diminished density due to elevation of temperature. In the daytime, in all probability, such expired air ascends nearly or quite to the ceiling-level. At night, however, if there are hanging lamps at the

height, say, of six or seven feet from the floor, the superheating of the air above them produces a hotter and lighter stratum, into which the merely warmed expired air cannot penetrate, except slowly by diffusion; and hence the effect of the lamps is almost to bring down the ceiling to the level of their flames, and practically to diminish, to this extent, the cubic space immediately available for respiratory purposes. Lamps at the table-level produce, of course, some heating of the air above them; but their effect is not nearly so perceptible. In the first place, they have more cubic feet of air to heat; and, in the next place, the expired air is expelled from the lungs actually into their heated stratum, instead of into a lower and cooler one. Hence it becomes mingled with the heated air, instead of being imprisoned below it, as when suspended lamps are used without adequate means of ventilation. It is a matter of common observation that rooms with suspended lamps become much more heated than others in which only table lamps are used; but the reason of the difference, although obvious enough when once it is pointed out, is far less generally recognised.

A few years ago, in the infirmary of one of the metropolitan workhouses, many deaths occurred, which were ascribed by coroners' juries to suffocation, and in which the cause of the suffocation was mainly the contraction of the otherwise available cubic space of the ward by the superheating of the upper half of it by suspended gas-burners.

Whatever source of light may be employed, whether gas, petroleum, or colza oil, the colour of the flame may be controlled at pleasure by the use of coloured globes or chimneys; and in this way many pleasing effects may be produced. The characteristic of all artificial light is that it is poor in violet when compared with daylight; and the first attempts to supply colour for illuminating purposes were in the direction of blue chimneys and blue globes or shades, by which, it seems to have been thought by some, the want of violet could be supplied. It will be evident, upon brief reflection, that the blue glass supplies nothing, and only transmits blue light by intercepting the other colours of the spectrum. If the artificial light is poor in violet to begin with, all that can be done by the glass is to display the small amount of blue which it contains, by suppressing the red and the green; and hence the total of the resulting illumination is very small indeed. In order to obtain light enough, from a gas or oil flame from which the red and green are thus filtered out, it is necessary to have flame enough to yield blue light enough for the required purpose; and this means a number of burners, a large consumption of fuel, and a great elevation of temperature. To all this there may be no objection, if the question of cost is unimportant, and if there is plenty of ventilation. The point to remember is that blue light cannot be obtained from gas or oil by the use of any coloured media, unless the total illumination, from which the blue light is to be taken, is of itself much in excess of the requirements of the position. If it were possible to enrich artificial light with violet, as might possibly be done by the introduction of some preparation of cobalt into the fuel, the existing preponderance of red and green would be rectified in the only proper manner.

For the purposes of general illumination, however, blue light would seldom be required. It gives, as a rule, rather a ghastly tone to the objects which it illuminates; and a landscape, looked at through a piece of blue glass, assumes almost a snowclad aspect. For eyes that are irritated by a preponderance of red and green,

it is sometimes desirable to redress the balance by the use of blue glass as an absorbent of these colours; but this is only for near work, and, generally speaking, for such work as reading and writing, which deals almost exclusively with black and white surfaces. A colour more suitable for general purposes is furnished by red or ruby glass, which affords an extraordinarily pleasant illumination of an apartment; and standing or hanging lamps have lately been made, chiefly by Messrs. Powell, of Blackfriars, in which the oil-vessel, as well as the shade and chimney, are made of glass of this and of other colours. My own drawing-room, for example, is lighted by ruby lamps, and the roseate tint which they cast over all the objects in the room is extremely pleasing. Something of the same effect has been lately to be seen in the auditorium of the Lyceum Theatre, but here the red light is hardly sufficient in quantity for the purposes of domestic lighting. In my own house, I have found the rose-coloured lamps much admired by ladies, and they certainly cast an exceedingly favourable tint over the complexion, besides setting off dress to much advantage. On passing out of the room on to the staircase, however, the ordinary gas-light there burning assumes a curiously blue tinge; and some minutes are required before the eyes become sufficiently accustomed to the change to cease to be conscious of any unnatural appearance. It would be easy, of course, to do away with this contrast, if it were objected to, by the simple expedient of using ruby shades on the stair-lights also.

The lighting of a dining-room is a matter which should be governed mainly by the style of its decorations, and also with reference to the two principal aspects which it may be made to assume. In some dining-rooms, the walls have been regarded merely as affording a frame, or setting, to the central table, which, with its decorations, its linen, its glass and its silver, and its environment of guests, partly consisting of ladies in brilliant toilettes, forms the picture. In others, the walls are adorned by objects upon which it is pleasant to look in the intervals between the courses; and it is manifest that the two styles will require very different treatment in the way of arranging the illumination, even if its amount remains the same.

As regards the materials employed, there is nothing to add to what has been formerly said, recommending gas or petroleum for economy, colza oil or candles where economy can be made subordinate to excellence. If the walls are generally decorative, and intended to be looked at during dinner, the best arrangement is to have two or more tall lamps on the sideboard, or on detached columns in other parts of the room, according to its size, together with a central suspended light, not shaded, but left free to throw its illumination upwards and around. In this way, the general lighting of the room and of the wall-surfaces may be accomplished; while that of the table should be secured by a sufficiency of single candles, so placed as not to intercept the view of the guests, and each of which may be covered by a little shade of silk or paper, of crimson or some other warm colour, so as to throw nearly all the light upon the table surface and upon the plates. If there should be any picture of especial beauty upon the walls, this should not be left to the general illumination of the upper parts of the room, but should have lights of its own on either side of it—perhaps single gas-burners on brackets projecting from the walls, and furnished with mirrors to illuminate the picture, while they conceal the sources of light from the guests. Where

the walls are of a dark colour, merely adapted to form a frame to the table, it will be sufficient to have two tall lamps on the sideboard; the central light may be shaded, and candles should be placed on the table itself as before.

When we come to lighting a room for work, a study or library, much of what has already been written will apply. In the first place, the light must be sufficient in quantity; there being few things more distressing to the eyes than insufficient illumination. Children are constantly permitted to work, or to prepare their lessons, by a light so defective that it involves the close approximation of the page to their eyes, and in this way becomes a fertile source of short sight and of squinting. Next, although the light should be ample as regards the particular object looked at, it should be so shaded that the room generally should be comparatively dark; so that the eyes, when raised in the intervals of occupation, as at the bottom of a page or at the close of a paragraph, should be raised to comparative darkness, by which they will be rested and refreshed, instead of to a still brighter illumination, by which they will be irritated and fatigued. The best position for an artificial light, as for a window, is a little above and to the left front of the worker, so that no shadow may be thrown by the right hand in writing; but if two lamps be used, they may be placed right and left, each of them extinguishing the shadow cast by the other. The late Dr. Copland, in his *Dictionary of Medicine*, states that for thirty years he made it a practice to read and write every night from about eight in the evening until two or three the next morning; and that for this purpose he used two argand lamps, fed with sperm oil, and which would burn for eight consecutive hours without interference or loss of light. The lamps were placed one on either side of a high desk, in such a manner that they were above the level of his eyes, which were sheltered from direct glare by the brows and eyelids. As already mentioned, sperm oil has been completely superseded by colza, and the many shades sold by the lamp-makers of the present day are calculated to reinforce the natural protection on which Dr. Copland relied.

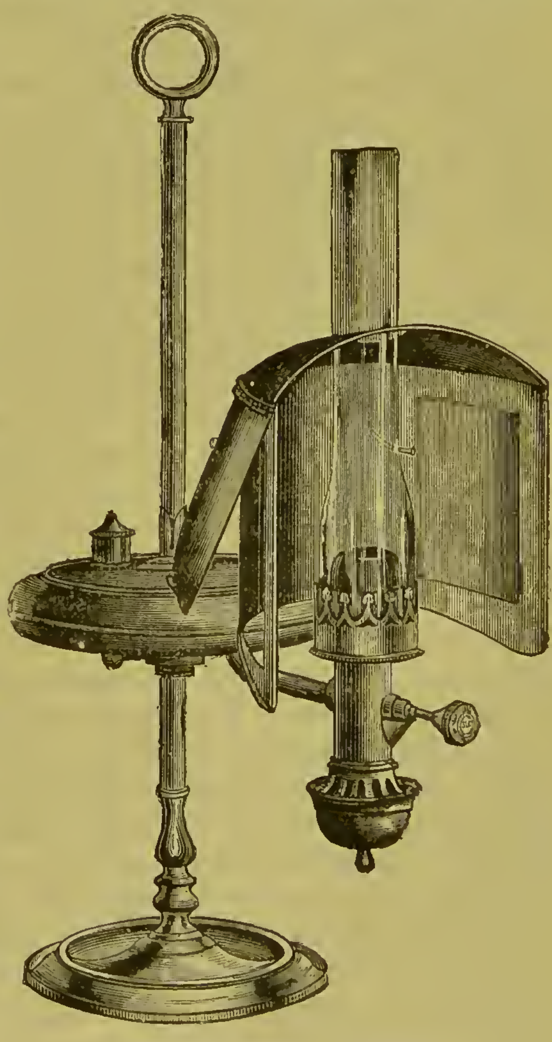


Fig. 199.—Silber Reading-lamp.

Perhaps the best lamp known at present for reading purposes is that manufactured by the Silber Light Company, under the name of the "Wellington." It has the ordinary Silber burner for either petroleum or colza, and is made, like the common "Queen's Reading-lamp" to slide up and down upon an upright stem; but

it differs from the latter in the fact that this stem passes through the oil-vessel, which turns upon it, in such a manner that the exact position of the burner can be determined by the touch of a finger. A still more noteworthy peculiarity is the construction of the shade, which is square instead of being circular, open in front, and furnished on either side with a lifting door, which can be set in any elevation and will remain where placed. The general result of this arrangement is that a flood of light can be directed, through the open front of the shade, to any part of the room which it is desired to illuminate; while sufficient for ordinary reading purposes reaches the table underneath the edges of the shade. If the book is at a higher level than the table, one of the sides of the shade can be lifted to any desired extent, to allow the light to reach this higher level, and the lamp can be adjusted to meet the wants of two different readers at the same time. The Wellington lamp is shown in Fig. 199.

The penalty to be paid for an increased amount of illumination, is, of necessity, an increased amount of heat; and hence the more perfect burners for table lamps of every description are objectionable to some people on account of the heat which they throw out. In some cases, no doubt, the objection may be a valid one; and light enough for the actual requirements of the case can be obtained from an inferior burner, which also affords less heat. But when the good light is necessary, and at the same time the heat is a disadvantage, the latter may be diminished in two ways. A solution of alum in pure water, filtered through coarse filtering paper, is as transparent to light as the water itself, but is almost entirely opaque to heat; and a flat cell of glass, like a photographer's dipping cell, filled with this solution, and placed between the lamp and the head of the worker, will intercept the heat in a satisfactory manner. The cell should be made of two squares of thin plate glass, cemented to narrow bottom and side strips by marine glue, and such an arrangement could be made by any dealer in philosophical instruments. It is difficult to design any table stand for such a cell which will not be liable to cast a shadow upon the work; and the best way is to have it suspended, either from a hook in the ceiling or from a table stand with a projecting arm, like that of a semaphore, so that the solid parts of the stand may be out of the way. Another, and perhaps a better device, is to place the light farther away, and to concentrate its beam upon the work by means of a globe of glass filled with water. Such a globe may be suspended in either of the ways mentioned above; and the superficial extent of the illumination which it affords will depend upon its precise position in reference to the flame. If the latter be placed in the focus of the globe, the beam of light issuing on the other side will be parallel, or of the same area as the circumference of the globe itself; if the flame be nearer to the globe than its focus, the beam will be more diffused; and if the flame be farther from the globe than its focus, the beam will be concentrated upon a smaller surface. A contrivance of this kind, by concentrating the light upon a small space, will sometimes allow an inferior illumination to be employed; and a glass globe has long been used for this purpose among the framework knitters of Nottinghamshire and Derbyshire, who are able, by its assistance, to weave underclothing by the flame of a single tallow candle, the light from which is focussed upon the exact portion upon which they are employed. Within the last year or two lamps fitted with water globes, or rather with semi-globes, have been sold at a shop near the Polytechnic in London, and have been employed at

some of the stations of the Metropolitan District Railway. I am acquainted with one or two instances of their use in private houses, where they have answered very satisfactorily.

In conclusion, I would endeavour to summarise, in a few words, the general principles which have been laid down, and to which attention should be systematically directed. For all occupations which require the close application of the eyes, the light employed should be sufficient in quantity, steady and uniform, so placed that, while the object of vision is adequately illuminated, the eyes themselves are sheltered from direct glare, not too heating, and not casting shadows upon the work. If these conditions are observed and if the deterioration of the atmosphere incidental to combustion is controlled by proper ventilation of the apartment, it may be safely laid down that work by artificial light is no more injurious than by daylight, and that it may be performed by healthy eyes and healthy persons to a practically unlimited extent.

WARMING AND VENTILATION.

By Douglas Galton, C.B., D.C.L., F.R.S.

CHAPTER XLVII.

GENERAL CONSIDERATIONS.

Composition of Normal Air—Carbonic Acid—Carbonic Oxide—Suspended Matter—Smoke and Fog—Decaying Organic Matter—Ozone.

It has been remarked as a singular fact, that whilst architecture made such wonderful progress during many ages, and has left monuments of its grandeur in almost every country, ventilation seems to have been almost entirely overlooked. This, however, is not strictly so. No doubt in the warmer climates, whence our civilisation chiefly came, open windows and doors were necessary during the greater part of the year; but the remains of Roman houses found in England exhibit methods of warming and ventilation which we might still do well to follow.

In the ages which followed the decay of Roman civilisation, the windows, ill-provided with protection from the weather, and the ill-fitting doors, afforded ample means for the access of air; and when fires were used, the huge chimney was itself a magnificent means of ventilation. When improvements in house-construction became more general, the evils arising from stagnant air in houses began to make themselves felt, and about a century ago the gaols, prisons, and convict-ships became the eloquent preachers of health to the English nation. These places were so unhealthy that many who were incarcerated died, or contracted such diseases as impaired their constitutions for life; and as if to show how the several members of society, high and low, are linked inseparably together, no one could come near the prisoners without danger of infection. At what is called the Black Assize, which was held at Oxford in 1577, although most of the prisoners escaped the epidemic, all other persons who were present, viz., the judge, the sheriff, and about three hundred others, died within forty-eight hours. At Taunton, in 1730, some of the prisoners infected the Court with the malaria they had brought from their cells, so that the judge, the sheriff, a serjeant, and more than a hundred others died. Dr. Lynd, in his "Essay on the Health of Seamen," asserts that the fleet was infected from the gaols, and that certain ships sent to America lost two thousand men in consequence. It thus became clear that something must be done to render the gaols more healthy; and hence arose the first efforts to ventilate them. The subject of ventilation having been thus started, the methods by which to ventilate dwellings began to attract much attention at the beginning of the present century.

Dr. Thomas Beddoes, in his Instructions drawn up in 1804 for the Medical Preventive Institution at Bristol, observed that "air by breathing becomes quite unfit to support life. If a creature be closely confined in a small quantity of air, it will live as long as there is any of that air fresh, and not exhausted; and after

wards it will die. Therefore, the air of all apartments requires changing. The air of a small shut-up room will be unpleasant and hurtful, though not immediately fatal. It would seem that children suffer more in proportion than grown people from too-confined or exhausted air."

To show how indispensable fresh air is to children, he mentions that in the Lying-in Hospital at Dublin 2,944 infants out of 17,650 died in the year 1782, within the first fortnight after their birth—that is, nearly every sixth child, or about 17 in 100. They almost all died in convulsions, of what the nurses call nine-day fits, because they came on within nine days after their birth. These children, many of them, foamed at the mouth, their thumbs were drawn into the palms of their hands, the jaws were locked, the face was swollen and looked blue, as though they were choked. This last circumstance led the physicians to conclude that the rooms in the hospital were too close, and hence that the infants had not a sufficient quantity of good air to breathe. This made them fall upon contrivances to change the air in the rooms where the children lived. Air-pipes, six inches wide, were placed in the ceiling of each room. Three holes, an inch wide, were bored through each window-frame; and a number of holes were made in the doors. Thus the rooms were kept sweet and fresh; and the consequence was that after the alterations not one child died where three used to die; and in 1788, 55 only died out of 1,496, or 36 per 1,000.

It is, however, remarkable that, with all our knowledge, the progress made in the ventilation of our dwellings has been, comparatively speaking, so slow. For so late as 1858, the Royal Commission on the Sanitary State of the Army reported that the ventilation of barrack-rooms was most defective, with the result "that the soldier was compelled to sleep in a fœtid and unwholesome atmosphere, the habitual breathing of which, though producing for the most part no direct immediate effects, probably lays the seeds of that pulmonary disease which was at that time so fatal in the British Army." This has since been remedied, and pulmonary disease has almost ceased in the British Army; and from the date of that report the subject has been so frequently pressed upon the public that the architect is at last beginning to consider that a knowledge of the principles of ventilation and of the other details of sanitary construction are as necessary to the efficient discharge of his responsibility to his clients as a knowledge of building materials. But there are still thousands of private houses, and especially business buildings, offices, &c., having fair and inviting exteriors, and comfortably, even luxuriously furnished, which are so deficient in a proper quantity and quality of air and light, as to render them breeding-nests of consumption, rheumatism, and other forms of disease.

We shall presently explain why the air in confined places occupied by living beings is subject to causes of deterioration which prevent its being as pure as the open atmosphere. Ventilation, which is the science which teaches us how to approximate the condition of the air under such conditions to that of the outer air, is dependent upon a knowledge of the composition and quality of air, as well as upon the causes which determine its motion; and it is necessary to a thorough comprehension of the subject that we should explain somewhat at length the several branches into which it is divided.

The air was originally regarded as an element. The ancient chemists made no distinction between the various elastic fluids, calling them all *air;* and they called

the air we breathe *common air*. In 1640, Van Helmont observed differences in airs, as they were termed, and he adopted the word *gas* or *gaz* to distinguish these from common air.

Air is essential to man's existence. The quantity of air actually inhaled and exhaled by an adult in twenty-four hours amounts on an average to about 360 cubic feet, or 2,000 gallons. What we take in and give out during twenty-four hours in the shape of solid and liquid food, occupies on an average the space of $5\frac{1}{2}$ pints, which is equal to $\frac{1}{3000}$ of the volume of the air passing through our lungs. This volume of air passing daily through the lungs weighs about 25lbs. avoirdupois.

Air taken under the most favourable circumstances, in free open spaces or on elevated ground, consists of the following constituents (Angus Smith) :—

$$1{,}000 \text{ parts} \begin{cases} \text{Oxygen, 209 to 211 parts; 209·6 mean.} \\ \text{Nitrogen, 789 to 791 parts.} \end{cases}$$

The oxygen is the hard-working, active substance that keeps up the fires, cooks the food, burns up the waste, purifies the blood. The nitrogen seems to be a mere diluent to prevent the oxygen from burning or destroying everything with fire and rust. Every analysis of air shows the presence in varying proportions of carbonic acid, vapour of water, organic matter, including many living organisms, ammonia, and suspended matter. The purity or impurity of the air and its effect on health depends upon the greater or less degree in which these various subsidiary matters are present.

The most important of the gaseous impurities in air which have an influence on health is carbonic acid, or carbon dioxide (CO_2). This gas is half as heavy again as air; it can be poured from one vessel to another just as water is poured, the carbonic acid sinking to the bottom of the vessel and displacing the air; nevertheless the processes whereby it is produced in the act of breathing raise its temperature and render it for a time specifically lighter than air. Thus it may ascend and accumulate near the ceiling. It would, however, descend when cooled. But it diffuses itself very rapidly through the air, and when once diffused, no length of time effects separation. Carbonic acid, if colder than the air above it, will diffuse more slowly; if warmer than the air near it, so as to be more close to the same specific gravity, it will diffuse more rapidly. The carbonic acid emitted with the breath is thoroughly mixed with the breath; and the expired breath, as a whole, is rapidly mixed with the air of the room.

When swallowed, the gas is harmless; but if it be inhaled, it acts as a narcotic poison. The undiluted gas kills instantly by spasm of the glottis. When diluted with air, so that the proportion of the gas present is about 12 to 14 per cent. (as in a room where charcoal in a chafing-dish has been burnt), it causes giddiness, hurried circulation, fulness in the head, noises, confusion, perhaps delirium, and finally coma, which may last a considerable time. Air containing 4 or 5 per cent. of carbonic acid gas (such as air once breathed) causes a sense of oppression, with headache, distress, and perhaps delirium or coma; such air containing even as little as 3 per cent. of carbonic acid cannot be breathed without great distress, and will probably produce insensibility; but the bad symptoms may probably be due in some cases as much to other impurities in the re-breathed air as to the carbonic acid, because in breweries and distilleries, where sensibly large proportions

of carbonic acid may be detected in the air, persons often breathe the air without being affected. Similarly, an atmosphere containing 1 or even 0·5 per cent. of carbonic acid gas (such as is sometimes found in ill-ventilated theatres) is distressing. On grounds of this nature it has been laid down that a proportion of 1 per cent. in air may be considered as the highest admissible quantity in air to be breathed by human beings. An atmosphere containing 16 per cent. of the gas instantly extinguishes a flame; in an atmosphere with 10 per cent. a taper still burns, but the flame is considerably dulled; in an atmosphere containing 8 per cent. a taper will burn readily. Thus a taper will burn in an atmosphere which may be dangerous to life.

The average amount of carbonic acid may be taken at ·04 per cent. in normal air, although it is not unfrequently as low as ·02 per cent., and sometimes as high as ·05 per cent. or more.

The experiments of Dr. Angus Smith show that in towns the oxygen in the air is not less than in the country districts, and that carbonic acid is slightly but not materially in excess. This is shown in the following table :—

IN MANCHESTER.

Oxygen.	Per 1,000.	CO_2.	Per 1,000 vols.
In fog and frost	209·100	Streets	0·403
Outer circle, not raining	209·407	Where fields begin	0·369
Suburb, in wet weather	{ 202·800 209·600	Streets in fog	0·679

IN LONDON.

Oxygen.		CO_2.	
Open places, summer	209·500	On Thames	0·343
Streets, November	208·850	Parks, open	0·301
		Streets	0·380

M. Reiset obtained from a year's observations, at a station in the country far from dwellings, and situated about four miles from Dieppe, an average of carbonic acid in the air of ·2942 per 1,000 volumes. The air above a crop of red trefoil in the month of June gave ·2898 per 1,000; and at a height of one foot from the soil, in a barley-field in July, ·2829 per 1,000; the corresponding amounts at the country station being ·2915 and ·2933 per 1,000 respectively. The presence of 300 sheep near the apparatus raised the proportion to ·3178 per 1,000. At Paris in May, 1873—75—79, the mean amount was ·3027 per 1,000. In a leafy coppice the amount, however, was ·2997 volumes in 1,000 of air, as against ·2902 volumes in the open. This difference may be due to the diminished quantity of light in the coppice. Messrs. Müntz and Aubin found in Paris, near the Conservatoire des Arts et Métiers, at about twenty feet above the ground, that the quantity of carbonic acid varied from ·288 to ·422, whilst in the open country extending towards Gravelle, in the vicinity of Paris, the amount was nearly constant at ·27; and on the Pic du Midi they found a variation of from ·28 to ·30.

It would have been probable that where animals are assembled in great numbers, and the processes of combustion, which also produce carbonic acid, are going on

rapidly, uninfluenced by vegetation, as in large cities, carbonic acid would accumulate and become injurious to life. The slight difference in this respect between the air of a dense city, that near the luxuriant vegetation of the country, and that on the top of a mountain, may be due to the remarkable property which all gases possess of diffusing themselves through each other's masses, more slowly, it is true, but with as much certainty, as they rush into a vacuum.

The influence of winds, also, sweeping through streets, arranged to favour the movement of air, will, under ordinary circumstances, effectually prevent any excessive accumulation in town air.

Mr. Armstrong made experiments on the diurnal variation of carbonic acid or (CO_2) in the air—a subject previously experimented on by Dr. Saussure and M. Truchot. The following are the general results he arrived at:—

1. That the normal amount of carbonic acid present in the air of the country is distinctly less than that usually stated, and that it does not exceed ·35 vols. in 1,000 of air.

2. That plants absorb carbonic acid during the day, and exhale it at night, and that vegetation, therefore, affects the quantity of carbonic acid present in the air, decreasing it by day, and increasing it at night.

That from this cause there is, during that part of the year when vegetation is active, at least 10 per cent. more carbonic acid present in the air of the open country at night than during the day.

A special experiment made upon a geranium plant in a close jar showed that if the plant did not actually absorb carbonic acid during the day, it exhaled none; while when it had absorbed carbonic acid in the daytime, at night large quantities were got rid of, thus fully substantiating the generally-accepted view that the carbonic acid absorbed by plants in the daytime is given out at night. On the other hand, Lewey's analysis on the Atlantic Ocean, one thousand miles from the coast, gave a decided excess of carbonic acid in the air in the day over that of the night. He attributes this to the action of the sunlight upon the ocean liberating the gases which it holds in solution. Some experiments of MM. Müntz and Aubin seemed to show that the quantity of carbonic acid gradually increases in cloudy weather and rain. And M. Marie Davis, of the Montsouris Observatory, says that the quantity of carbonic acid in the air in the neighbourhood of his observatory varies in a sensible manner from one year to another, from one month to another, and indeed on successive days.

In confined spaces occupied by numerous persons, this gas (CO_2) will frequently be found in excess. The carbonic acid in dormitories has been found to be ·52 per 1,000 volumes; the amount in a bed room on rising in the morning ·48; and in a well-filled school-room ·72 per 1,000 volumes.

Pettenkofer has suggested a convenient test for carbonic acid by exposing a given quantity of the air to be tested to contact with a given quantity of clear lime-water. The carbonic acid is absorbed by the lime, and the causticity of the lime-water is proportionately diminished. Hence the difference in the degree of causticity of the lime-water before and after exposure to the air which is being tested will enable the amount of carbonic acid which has united with lime to be calculated.

There are many other causes of impurity in air, and carbonic acid (CO_2) is,

perhaps, less important on account of its own special action than because of its use as a measure of the purity of the air.

Carbonic oxide (CO_1) is eminently poisonous. Less than 0·5 per cent. has produced poisonous symptoms, and 1 per cent. rapidly produces fatal results. This gas is formed by the imperfect combustion of carbon.

There are various suspended matters in air which produce disease from mechanical causes, such as the dust which in Egypt produces a sort of ophthalmia. Bronchitis and lung-disease prevail in many factories, arising from the inhalations by the workmen of the dust of coal, sand, and steel, or of particles of cotton or hemp. Stonemasons suffer from inhalation of stone-dust. The Guards suffered largely about eighteen years ago from lung-disease; one of the contributing causes was assumed to be the quantity of pipe-clay they inhaled in the process of cleaning their white cloth fatigue-jackets. House-painters suffer from the dust of white lead; though in this, as in many cases, the persons suffer as much from swallowing particles, in consequence of not washing off the dirt from their hands before eating. In factories cotton-dust was at one time a dangerous source of disease, because, when inhaled in breathing, it clogged the lungs and led to disease and death; but in all well-conducted factories arrangements are now made for drawing the dust away by a fan as soon as it is generated. In towns the suspended matters in air which are of most importance consist of the dust from refuse, chiefly organic matter from horse-dung and the imperfectly-consumed particles of coal.

Mr. Romanes mentioned on a recent occasion that he had found in examining after death the lungs and air-tubes of persons who had lived in the densely-inhabited parts of London, that they were coated in many places with soot and carbon, and thus able to act much less efficiently than the lungs of people who had breathed clearer air.

The aeroscope invented by Pouchet offers an easy mode of examining this class of suspended matters in air. Air is drawn, by means of an aspirator, through a funnel, the end of which is brought to a fine point, immediately below which is placed a slip of glass moistened with glycerine. The ends of the funnel and glass are enclosed in a little air-tight chamber, from which a small glass tube passes up, and is connected by means of india-rubber tubing with an aspirator. The air can only pass into the aspirator through the funnel, and, as it does so, any solid particles carried down with the current impinge on and are arrested by the glycerine, and can be afterwards examined by the microscope. An aspirator can be made for a few shillings. Another plan is to draw the air through a solution of pure water, or permanganate of potash. All the solid particles are retained at the bottom of the vessel, and can be afterwards examined with the microscope.

There are, however, other floating particles in the air which elude these rough methods of filtration. Dr. Tyndall's beautiful and delicate experiments show that such forms of dust will pass through even caustic potash and sulphuric acid, but can be intercepted by closely-pressed cotton wool.

The question of smoke has recently begun to occupy much attention; and there is no doubt that in our towns, when the public mind shall have become sufficiently educated to understand the importance of purity of air, a radical change will take place in our methods of providing warmth in our houses.

Dr. Aitken, in a paper published in the "Transactions of the Royal Society of

Edinburgh," showed that fog and rain were caused by the dust and fumes present in the atmosphere; and that air freed from dust by filtration gives no fog whatever. Air freed from dust may be supersaturated with moisture, and the moisture will remain invisible in its vaporous form; but when dust or fumes are introduced, the vapour will condense upon the dust-particles and become visible. In illustration of this, Dr. Aitken mentions the following very simple experiment:—Take a receiver filled with the ordinary air of a room, which always contains an enormous number of particles of dust; let as much steam be blown in as will form a dense fog. Now, allow this fog to settle, but do not allow any dusty air to enter. After the fog has settled blow in more steam. Again a dense fog will be condensed on the dust which escaped the first condensation. Allow this again to settle, and repeat the process a number of times, when you will find, after many repetitions, that there is still fog forming. But it will also be noticed that after each condensation the fog becomes less and less dense, till at last it ceases to appear as fog; but on closely looking into the receiver the condensed vapour will be seen falling as fine rain. When the steam was blown in the first time the fog was very fine-textured; each particle was so small it floated easily in the air. After each condensation the fog became less dense; it at the same time became more coarse-grained and heavier, and was seen falling slowly. Near the end no fog was visible, and nothing but a fine rain to be seen falling. If the air were still further purified, even the rain seemed to cease.

The conclusions which may be drawn from these experiments are—1st, that when water vapour condenses in the atmosphere, it always does so on some solid nucleus; 2nd, that the dust-particles in the air form the nuclei on which it condenses; 3rd, if there were no dust in the air there would be no fogs, no clouds, no mists, and probably no rain.

The results of the action of dust in producing cloudiness are not always alike. In one case the condensed vapour takes the form of a fog, so fine that it easily floats in the air and never seems to settle. In another case the cloudiness is coarser-grained and settles down slowly, and in another case it is a very coarse-grained mist, which falls quickly. It would appear that, when the dust is present in great quantities, the condensed vapour forms a fog, because as there are a great number of dust-nuclei, each nucleus only gets a very little vapour, and is not made much larger or heavier, so it continues to float in the air. As the number of dust-nuclei diminish, the amount of vapour condensed on each particle increases; their size and weight therefore also increase. So that as the density of the cloudiness decreases the size of the particles increases, and their tendency to settle down also increases. Fogs will, therefore, only be produced when there is abundance of dust-nuclei and plenty of vapour. There is probably also something due to the composition of the dust-particles; some kinds of dust seem to form better nuclei than others.

This dust in the atmosphere will have many sources. Everything in nature which tends to break up matter into minute parts will contribute its share. In all probability the spray from the ocean—after it is dried and nothing but a fine salt-dust left—is perhaps one of the most important sources of cloud-producing dust. This form of dust is ever present in our atmosphere, and is constantly settling on every object, as evidenced by the yellow sodium flame seen when bodies are heated. There is also meteoric dust, and volcanic dust, and condensed gases. Mr. Langley, the American astronomer, when making observations on the sun at about

13,000 feet above the sea-level, on Mount Whitney, nearly 200 miles from the Pacific Ocean, saw dust-clouds which he computed to be very far above him, and which it was supposed were composed of fine loess blown from the plains of China.

Dr. Tyndall tells us that solar light, in passing through a dark room, reveals its track by illuminating the dust floating in the air. "The sun," says Daniel Culverwell, "discovers atomes, though they be invisible by candle-light, and makes them dance naked in his beams." When we look at a beam of light thus traversing a dark room, we are struck by the marvellous amount of dust revealed ever floating in our atmosphere, and which under ordinary conditions of light are not observed. When the air containing this dust is highly heated or passed through a flame, all these motes are destroyed, and the path of the sun's rays becomes invisible. One might hence naturally conclude that air which has passed over or through a flame, or through a fire where the combustion was perfect, ought to be nearly dustless, and therefore ought not to be a good medium for fogs. But, according to Mr. Aitken's experiments, although heating the air by flame or heated metal may cause the dust-motes to become invisible, and may destroy the organic matter in the dust, it does not remove all the dust, but seems rather to increase the number of the particles. The heat would seem to destroy the light-reflecting power of the dust by breaking up the larger motes into smaller ones, and by carbonising or in some way changing their colour, and thus making them less light-reflecting.

It would follow from this that, powerful as the sun's rays are as a dust-revealer, we have in the fog-producing power of the air a test far simpler, more powerful and delicate, than the most brilliant beam at our disposal. When steam escapes into the air it condenses on the dust-particles, and thus, by simply magnifying their size, makes their number evident to the eye. Our "breath," as seen on a cold morning, is evidence of the dusty state of the air. If it were not for dust we should never see our "breath," nor would wreaths of steam be seen floating in the air from steam boilers, nor would our railway-stations and tunnels be thick with its cloudiness.

It is not only the visible dust-motes seen in the air that form the nuclei of fog and cloud particles, as these may be all destroyed by combustion, and yet the air remain fog-producing. Perhaps the most active of all substances in producing fog is sulphur when burned. The fog produced when steam has been blown into air in which a very little sulphur has been burned is so dense that it is impossible to see through a depth of more than five centimetres of it. The sulphides when burned also give similar results.

Hence combustion under all conditions is bad as a fog-producer; bad, whether the combustion be perfect, as in a Bunsen flame and a clear fire, or imperfect, as in a smoky flame and smoky fire. It is, therefore, hopeless to expect that by adopting fires having a perfect combustion—such as the gas fires, now so much advocated—we would thereby diminish the fogs which at present, under certain conditions, envelop our towns, and give rise to so much that is both disagreeable and detrimental. All fires, however perfect the combustion, are fog-producers when accompanied by certain conditions of moisture and temperature.

Dr. Aitken sums up his experiments with the following suggestive observations :—

"All our present forms of combustion not only increase the number and

density of our town fogs, but add to them evils unknown in the fogs which veil our hills and overhang our rivers. In the country our fogs are white and pure, while in towns they are loaded with smoke and other products of imperfect combustion, making the air unwholesome to breathe and filthy to live in. But why should these two miseries always come together? Either the fog or the smoke is bad enough alone; why should the smoke, which usually rises and is carried away by the winds, fall to the ground when we have fogs? I think that the conditions which account for the fog also account for the smoke falling. When we have fogs the atmosphere is nearly saturated with vapour, and the smoke-particles, being good radiators, are soon cooled, and form nuclei on which the vapour condenses. The smoke-particles thus become loaded with moisture, which prevents them rising, and by sinking into our streets add their murky thickness to the foggy air. This seems to explain the well-known sign of falling smoke being an indication of coming rain. That the colour or blackness of what is called a pea-soup fog is due to smoke is, I think, evident from the fact that a town fog enters our houses and carries its murky thickness into our rooms, and will not be induced to make itself invisible, however warmly we treat it. It will on no account dissolve into thin air, however warm our rooms, for the simple reason that heat only dissolves the moisture and leaves the smoke, which constitutes a room-fog, to settle slowly, and soil and destroy the furniture. If the fog were pure —that is to say, were a true fog, and nothing but a fog, such as one sees in the country—it would dissolve when heated, as every well-conditioned fog does. A fog is never seen inside a country house.

"But while admitting the bad effects of a fog aggravated by smoke, yet we must not forget the probable good effects of the smoke. It has been elsewhere pointed out that the suspended smoke or soot may exercise the well-known disinfectant properties possessed by the different forms of carbon. Before utterly condemning smoke, it will be necessary fully to consider its value as a deodoriser. And, further, we must remind those who are crying for more perfect combustion in our furnaces and grates, that combustion, however perfect, will not remove or diminish fogs. It will, however, make them cleaner, take away their pea-soupy character, but will not make them less frequent, less sulphurous, less persistent, or less dense.

"We have shown that sulphur in its different forms, when burned, is most active as a fog-producer. Now, almost all our coals contain sulphur, which is burned along with the coal, and it is certainly worth considering whether some restriction ought not to be put on the amount of sulphur in the coal used in towns. The quantity of burned sulphur that escapes from our chimneys is very great. Suppose we put the amount of coal annually consumed in the London district at a little over 7,400,000 tons. Now, the average amount of sulphur in English coal is more than 1·2 per cent. Suppose that it is 1 per cent., so as to be within the mark, that would give 74,000 tons of sulphur burned every year in London fires, or at the rate of about 200 tons in an average day; and the amount will be greater in a winter day—a quantity somewhat alarming—and quite sufficient to account for the density of our fogs. Its presence and effects during our fogs are very evident in the discoloured metal on our street doors, and in our houses.

"But, like smoky fires, burnt sulphur is not an unmitigated evil. During fogs

the air is still and stagnant; there is no current to clear away the foul smells and deadly germs that float in the air, and which might possibly be more deadly than they are if it were not for the powerful antiseptic properties of the sulphurous acid formed by the burning sulphur. Before condemning the smoke and fog-producing sulphur, it would be well for us thoroughly to investigate their saving properties, and weigh their advantages, lest we should substitute a great and hidden danger for an evident but less evil."

The general conclusions arrived at by Dr. Aitken are of such importance that they cannot well be omitted here. They are as follows :—

1. That as regards cloudy condensation of vapour in our atmosphere, there is dust, and dust. Some kinds of dust have such an affinity for water that they determine the condensation of vapour in unsaturated air, while other kinds of dust only form nuclei when the air is supersaturated—that is, they only form free surfaces on which the vapour may condense and prevent supersaturation. In many of the experiments it was noticed that when the air was nearly purified, when all the dust which had an affinity for vapour had received its burden of water and settled down, that there remained, to near the end of the experiment, some particles which seemed to require a certain degree of supersaturation before they became active. In highly supersaturated air all kinds of dust will form nuclei, and determine condensation; but in unsaturated air, only those kinds of dust which have an affinity for water will be active.

2. This affinity which some kinds of dust have for vapour explains why it is that our breath and escaping steam dissolve even in foggy air. The large cloudy particles in our breath and in condensed steam tend to evaporate in the same air in which condensation is taking place, because the dust-particles on which the breath has condensed have had their affinities more than satisfied; they therefore tend to part with their surplus by evaporisation in the same air as those particles which have not had their affinities satisfied tend to condense it.

3. Dry fogs are produced by the affinity which the dust-particles have for water vapour, in virtue of which they are enabled to condense vapour in unsaturated air. From the experiments with chloride of sodium, from the known affinity of that salt for water, and from the fact that great quantities of salt-dust are ever present in the air, it is evident that if it is not *the* cause of dry fogs in the country it must play some part in those phenomena. There are doubtless also other kinds of nuclei having affinities for water which will cause dry fogs.

4. That the products of combustion of the sulphur in our coals, especially when mixed with the other products of combustion, such as ammonia, have the power of determining the condensation of water vapour in unsaturated air, and give rise to a very fine-textured dry fog; they are probably one of the chief causes of our town fogs, as they have a greater condensing-power than the products of combustion of pure coal.

Though there may seem to be but little doubt that products of combustion when mixed with the sulphur compounds are most active producers of town fogs, yet we must not rest satisfied that they explain everything. There may be other causes at work, and conditions yet requiring explanation; and the nuclei, though found in far greatest abundance in the air of our towns, will no doubt be also found in the air of the country. Professor Tyndall has shown that light decomposes certain

gases and vapours, and that this decomposition is greatly aided by the presence of other gases or vapours. It seems, therefore, probable that the sun's rays will decompose some of the gases and vapours in the air, and if these decomposed substances have a lower vapour-tension than the substance from which they are formed, they condense into very fine particles. These particles may be solid or liquid, and will form nuclei for the condensation of water vapour. We know that there are ever present in our atmosphere great quantities of chloride of sodium and other kinds of dust which have affinities for water. These dust-particles by their affinities for water vapour cause condensation to take place in unsaturated air, and if present in great quantities give rise to dry fogs. Moreover, if there be an affinity between the dust and the vapour, each particle of dust tends to take the same amount of vapour, and if one particle get more than its proportion the others tend to rob it of its surplus. This evidently tends to equality in the size of the cloud-particles, and tends also to prevent any of them falling through the others, and thus prevents it beginning to rain.

But after the affinities of the dust-particles are satisfied, this tendency to stability no longer exists. The growth of the particles becomes unequal, and the larger drops or particles in a cloud will tend to prevent the smaller ones growing after the affinities of the nuclei are satisfied. It would appear, then, that condensation will always begin in our atmosphere before the air is saturated.

There are other questions connected with dust in the air to which we must now allude. This dust contains organic matter in a form from which bacteria are developed. This floating matter may not be uniformly distributed, but probably occurs in clouds denser in one place than in another.

Recent observations at the Montsouris Observatory at Paris show that the air taken from the centre of Paris, and especially air from the vicinity of sewers, produced bacteria in greater quantities than air taken from the more open country. It also appeared that whilst the numbers of bacteria were comparatively small from air collected during wet weather, they increased as the soil became drier, but decreased again under the influence of bright sunshiny weather.

We are still only on the threshold of knowledge as to how diseases are propagated. The experiments of Tyndall, Pasteur, and Koch are making it more probable day by day that many of the most fatal forms of disease may be propagated by some one or other form of organism which finds its way into the system. They show that, given a satisfactory "nidus," the development of the disease-germ is almost certain to follow; and yet, how is it that in localities where disease-germs must on this theory often be filling the air, so many persons escape the disease? Why is it that one individual develops the disease, and another, exposed apparently to the same influences, and possibly in a greater degree, escapes?

We have taken the first step in progress by ascertaining what will cause the disease. The next step is to follow the example set by Lister, and ascertain what will prevent the individuals exposed to the *disease-influence* from affording a satisfactory "*nidus*" for the reception of disease-germs.

One thing we do know from past experience, and experience which is fortified by the recent inquiries into disease-germs; and that is, that air which has been previously breathed by others tends to permit certain diseases to spread, whilst an abundance of fresh air is a great preventive to the spread of disease.

We know that phthisis and other diseases prevail where persons breathe air rendered impure by the organic matter thrown off from the human body in the process of breathing and transpiring. We know, by what was done in the British army, that tubercular disease can be diminished by good ventilation and other sanitary arrangements. Dr. Tyndall has shown us that putrefaction is only another form of organised life. We know that malaria appears to arise from the poison of decaying moist vegetable matter in marshes and forests; and it has been suggested by Drs. Klebs and Crudelli that it is caused by micro-organisms present in the water of, or floating in the air over, such localities. We also know that typhoid fever prevails in air which rises from the putrefying substances in sewers; and that in camps men have suffered from typhoid fever in consequence of their tents being placed near to manure-heaps. We know that air rendered impure by breathing, by the presence of decaying organic matter, and by other preventible causes, induces a low state of vitality. And on the other hand, we know that pure air such as that coming over the sea, or that on the top of a mountain, is eminently restorative of vital energy; and we believe that a person in a low condition of health is less able to resist disease than one whose vital energy is unimpaired.

So long as air is in movement out of doors, the products of vegetable and animal waste are continually removed from the air by oxidation. Much of this oxidation is probably due to the action of ozone, and would not be effected by ordinary or inactive oxygen. Ozone is oxygen in an altered or allotropic condition, and appears to be formed by the passage of the electric spark through dry oxygen, or by slow oxidation of phosphorus and other essential oils in presence of moisture. Ozone is insoluble in water. Ozone is rarely, if ever, absent in fine weather from the air of the country; but it is more abundant, on the whole, in the air of the mountain than of the plain. It is also said to occur in larger quantity near to the sea than in inland districts. It has been found to an unusual amount after thunderstorms.

There is great variety of opinion as to the atmospheric conditions which produce ozone. According to some observers, the amount of ozone in the air is greater in winter than in summer, and greater in spring than in autumn; but, according to other observers, it is greater in spring and summer than in autumn and winter. Ozone has usually been found more abundantly in the air at night than by day; but again, some careful observers have found the reverse of this statement to be true. No connection has yet been proved to exist between the amount of ozone in the atmosphere and the occurrence of epidemic and other forms of disease.

Ozone is rarely found in the air of large towns, unless in a suburb when the wind is blowing from the country. An experiment made last autumn at the end of the pier at Brighton showed the presence of ozone when the wind was blowing off the sea, but no ozone was present when the wind blew directly over the town; and it is only under the rarest and most exceptional conditions that it is found in the air of the largest and best-ventilated apartments. It is, in fact, rapidly destroyed by smoke and other impurities, which are present in the air of localities where large bodies of men have fixed their habitations. The permanent absence of ozone from the air of a locality may, however, be regarded as a proof that the air is adulterated air. Its absence from the air of towns and of large rooms, even in the country, is probably the chief cause of the difference which every one feels when

he breathes the air of a town or of an apartment, however spacious, and afterwards inhales the fresh or ozone-containing air of the open country.

The amount of ozone in the atmosphere is extremely small, and an excess of ozone is destructive to life; thus the respiration for a very short time of oxygen containing about $\frac{1}{240}$ part of ozone is certainly fatal to all animals; whilst similar animals will live in good health for months after respiring oxygen alone for thirty-seven hours, the carbonic acid being removed during the experiment.

The value of ozone as a purifier of air has received some practical application both in this country and in the United States; and in New York an apparatus for producing ozone from the slow combustion of phosphorus is sometimes used in crowded offices as a means of purifying the air. Of the useful effects of this apparatus there are no recorded experiments. It is, however, to be observed that, whatever may be the beneficial effect of ozone in destroying putrefying organic matter, ozone in excess is a deadly poison.

CHAPTER XLVIII.

Deterioration of Air in Confined Spaces—Effect of Respiration—Danger from re-breathed Air—Dr. Leeds' Experiments—Army Experience—Town Air—Density of Population.

THE process of breathing takes air into the lungs and expels it in a deteriorated condition, because the air is thereby deprived of its vital oxygen, which is replaced by carbonic acid, by a large amount of water, and by a variable quantity of animal (organic) matter. This organic matter, on an average, may be estimated at thirty or forty grains a day for each adult. It consists of small particles of skin (epithelium), fatty matters, and a peculiar fœtid (organic) vapour, which is the cause of the disagreeable odour in close and crowded rooms, which gives rise, by its decomposition, to products detrimental to health.

If this air be passed through water, the latter soon exhibits all the phenomena of putrefactive fermentation.

The water given out in respiration is loaded with animal impurities; it condenses on the inner walls of buildings, and trickles down in fœtid streams, and evaporates or sinks into the walls, leaving the impurities on the surface. On this account, a peculiar disagreeable smell may often be perceived in rooms which have been long inhabited, especially rooms which have been inhabited by large numbers of persons, and the wall-surfaces of which have not been often renewed. The oxygen is, of course, diminished in the direct ratio of the consumption of carbon and hydrogen in the system. But a man vitiates more air than is needed for respiration; an uncertain quantity of fresh air is both needed and vitiated in each minute by transpiration. A constant exhalation of carbonic acid transpires from the skin, by no means so large as that emitted from the breath, but probably one-fourth or one-fifth as great. The regularity of this transpiration nearly equals that of respiration. Accompanying this, it is probable that an absorption of oxygen corresponding to the equivalent of oxygen in the carbonic acid takes place.

Experiments have been made to determine the amount of carbonic acid which is given out in the process of breathing. A subsistence diet, sufficient for the internal work of the body only, is a little under three thousand grains of carbon daily, yielding about 13·6 cubic feet, or about 0·57 cubic feet per hour of CO_2

Angus Smith, in his experiments, was unable to find more than 0·4 cubic feet per hour of CO_2 given off; but the experiments of Pettenkofer showed that in a state of repose an adult gave off about 0·7, and in a state of active work 0·9 to 1·0, or more.

The numbers correspond pretty closely with theoretical calculation, but if the number 0·6 cubic feet be taken to allow for difference of age, weight, and sex, it will be well within the mark in the calculation.

The constitution and usual diet of the person experimented on no doubt influences the result. Temperature also has an effect.

With a high temperature, the quantity of oxygen present in the air is diminished. Thus, a cubic foot of dry air at 32° weighs 566·85 grains, and if the proportion of nitrogen and oxygen be assumed to be by weight seventy-seven and

twenty-three per cent., and the slight amount of carbonic acid be neglected, there will be in a cubic foot :—

436·475 grains of nitrogen.
130·375 grains of oxygen.

566·850.

As a man draws, on an average, when tranquil, 16·6 cubic feet per hour into his lungs, he will thus receive $130 \cdot 375 \times 16 \cdot 6 = 2{,}164 \cdot 2$ grains of oxygen per hour.

At a temperature of 80°, the foot of air weighs 516·38 grains, and on the same assumption is made up by weight of—

397·61 grains of nitrogen
118·77 grains of oxygen.

516·38.

Therefore, in a hour, if a man withdraws 16·6 cubic feet, he will receive $118 \cdot 77 \times 16 \cdot 6 = 1{,}971 \cdot 6$ grains of oxygen per hour. Or, in other words, in an hour he would receive 192·6 grains of oxygen less with the higher temperature; that is to say, he would breathe an amount equal to about 90 per cent. of the amount he would breathe at the lower temperature.

Experiments have been tried with birds and animals which tend to show that there is less than one half exhaled when breathing air at a temperature above 86° Fahrenheit than there is when breathing air at a temperature near the freezing-point. This is practically illustrated by the fact that when we are breathing air at this very low temperature we are twice as active, and can do twice as much work, as when we are breathing air of nearly the temperature of our own bodies. We know how very languid and good-for-nothing we feel on a hot summer's day; and, on the contrary, how fresh and vigorous we feel in the open air of a cold bracing winter's day.

The amount of vapour given out by the breath varies; but taking the amount from skin and lungs together, it may be assumed at about 30 ounces per diem, or about 550 grains per hour, enough to saturate about 90 cubic feet of air at a temperature of 63° Fahrenheit. The amount of organic matter has been variously estimated, but there are hardly any trustworthy experiments on record.

As already mentioned, this organic matter is highly poisonous; and it is as much from the presence of this as from carbonic acid in re-breathed air that injury arises.

The virulent nature of this poison of impure air and the rapidity of its action are exemplified by many instances, of which we will select one or two, which are, however, well known.

In the year 1756 there were 146 individuals confined in a small cell known as the Black Hole of Calcutta. This cell was 18 feet long by 14 feet wide, being so small that the last person of the 146 had to be crushed in upon the rest with violence as the door was closed and locked. The only means of ventilation were two small holes. In the morning 123 corpses were taken out, and twenty-three beings who could scarcely be said to be alive.

The steamship *Londonderry* left Sligo for Liverpool on 2nd December, 1848,

and stormy weather coming on, the captain forced 200 steerage passengers into their cabin, which was 18 feet by 11 feet, and 7 feet high. The hatches were battened down and covered with tarpaulin. When the cabin was opened seventy-two persons were found dead, and several expiring.

Horace Walpole mentions that in 1742 a set of jolly Dogberries, virtuous in their cups, resolved that every woman out after dark ought to be locked up in the round-house. They captured twenty-six unfortunates, and shut them in with doors and windows fastened. The prisoners exhausted their breath in screaming. One poor girl said she was worth eighteenpence, and cried that she would give it gladly for a cup of water. Dogberry was deaf. In the morning four were brought out dead, two dying, and twelve in a dangerous condition.

These were all deaths caused by breathing over again air which had been once breathed without any fresh air to dilute it.

These cases of suffering and death may be said to have arisen from causes out of the control of the victims. But in many instances the sufferers have themselves created the evils.

The following instance of disease directly traceable to the generation of impure air in a room from carelessness was mentioned nearly eighty years ago by Dr. Beddoes, and deserves to be alluded to, as illustrating the importance of opening out bed-clothes in the morning, and keeping dirty linen in baskets instead of in closed boxes or drawers. One man of the Horse Artillery at Woolwich was admitted into the hospital with a suspicious fever, next day another. This excited inquiry. It was found that they came from two different barrack-rooms. These were followed by other men, in all amounting to eight, three of whom came from a separate room, the rest from the same rooms. All the rooms whence the infected men came were found to have entirely different bedding from the rest of the barracks. The Horse Artillery being a corps in constant readiness for service, and whose appointments were always complete, had for convenience of carriage hammock bedding. The hammocks were rolled up tightly every morning the moment the men rose, and they were unloosed when they went into them at night. At this time there had been so much and so constant rain, that this bedding had not been aired or opened for a single day for at least two months. The hammocks with their bedding were examined, and the moment they were opened a very peculiar nauseating smell was perceptible. Immediate steps were taken to alter the bedding, and no further mischief took place.

Here an infectious fever evidently arose from the confinement of the effluvia (or fumes, vapours, exhalations) from a man's own person for a term of about two months.

When the effects do not go thus far, the breathing of contaminated air gradually lowers the standard of health; and either alone, or combined with want of food or exercise, or with excessive work and irregular habits, becomes a fertile cause of consumption and diseases of the lungs and other organs. An atmosphere of this kind, if not capable of generating, certainly causes a more rapid spread of such diseases as fever, small-pox, scarlatina, &c., as much by favouring the development of the special poison as by rendering the body less healthy, and therefore less capable of resisting the disease-poison.

Speaking of this, Dr. Carpenter says in his work on "Human Physiology,"

that the "purity of the atmosphere habitually respired is essential to the maintenance of that power of resisting disease which, even more than the ordinary state of health, is a measure of the real vigour of the system. For, owing to the extraordinary capability which the human body possesses of accommodating itself to circumstances, it not unfrequently happens that individuals continue for years to breathe a most unwholesome atmosphere without apparently suffering from it, and thus when they at last succumb to some epidemic disease their death is attributed solely to the latter, the previous preparation of their bodies for the reception and development of the zymotic poison being altogether overlooked."

The effect of fresh air is to accelerate the functions of the body, so as to enable more work to be done. Dr. Beddoes mentions a case in which fresh air was supplied to a work-room where some dressmakers had been working in a very close atmosphere. The dressmakers complained that the ventilation increased their appetite, and that unless their wages were raised to enable them to buy food they would prefer to have the close atmosphere restored; but they did much less work in a day in the close atmosphere than they did with the due amount of ventilation, and the additional work was worth more than the additional sum for wages.

Dr. Leeds, of New York, mentions an experiment which exemplifies this same thing.

The account he gives is too graphic to omit: "I took six half-gallon jars, six quart jars, and six pint jars, making eighteen in all, into all of which I enticed flies. Some had twenty, some forty, and some sixty. Two of the bottles of each size, making six in all, I filled with my breath, and sealed up tight; two of each size I simply sealed tight, but filled with pure air; and the other six, two of each size, I covered with coarse netting, so as to allow of a free circulation of air and keep the flies confined. It was in summer, and I closed them up at 6 p.m., the sun about an hour high; I observed their condition at intervals of an hour. At the end of the first hour those confined in the breath were very stupid, many of them tumbling about from side to side, and none able to fly. Those confined in the pure air were moderately lively, about half of them could fly from side to side, and were just as much at the bottom as at the top of the jar. But a very different scene was presented as the others with the circulating air were examined; they were all crowded to the fresh air opening, their feet sticking up through the netting, and there they remained with much persistence. If driven away, they would immediately return, and in one, there being more flies than room at the fresh air opening, they had to take turns standing at the window: which reminded me of what I observed at Nashville jail, which was so shamefully crowded, and with so little air, that each prisoner was allowed just so many minutes to stand by the little hole that admitted the fresh air; and this was considered so great a privilege, each one waited with the greatest anxiety and impatience for his turn, and they would never miss, night or day.

"So it seemed to be a great privilege with these flies, but I suppose they did not take their turn with so much punctuality.

"In two hours some of the flies in the breath seemed nearly dead, the others much the same. At ten in the evening no particular change. Next morning, at six o'clock, no marked difference; those in the breath a little more stupid,

and two or three apparently dead; one or two in the confined pure air about dead. On being put out in the bright morning sun they revived wonderfully: those with the circulating fresh air kept up a perfect humming, and the others revived very much; but few, however, of those in the breath were able to fly even with this extra stimulus. At 10 a.m. I went to town, and at 5 p.m. returned home. I expected to find all those in the breath dead, those in the confined pure air about half-dead, and those in the circulating pure air as lively as ever; but to my utter astonishment and disgust I found every one of those in the pure air stark dead—not a vestige of life in a single fly. Those in the pure confined air were about half dead, and nearly the same proportion of those confined in the jar with the breath. But they did not die even in these with perfect regularity.

"Those in the breath died a little the fastest; but very soon after I noticed another form of animal life, in the shape of maggots, which soon attained the size of the original flies.

"Some of these flies in the breath and confined pure air lived ten days (there would be but one or two in a bottle that lingered so long); the other animal life lingered some three weeks. These bottles, upon being opened, emitted a horrid stench.

"But the bodies of the flies confined in the pure circulating air never had the least unpleasant odour, were never touched by any insect, and three months after their bodies were just as bright and clear as the day they died. Thus, those in the foul air lived ten times as long as those in the pure air. Now the practical lesson this teaches is what I before asserted, that when you breathe pure air you live faster, so to speak; you are much more lively; you use much more exertion; but all this exertion requires power, and, universally, power requires food.

"Now these flies in the circulating pure air no doubt used more exertion or did more work in the few hours they were living without food than did those which lived ten days—their bodies were so thoroughly used up there was nothing but skin and bones left."

This explains what might otherwise seem a strong argument against breathing pure air.

We find many poor people living in poor unventilated houses, who exist to quite an advanced age; but they are often sick and feeble, and if they both live and work in close, unventilated rooms, they will eat much less, and do much less work, than those who live and work in fresh air. The course which a person should pursue who desired to fast, like Dr. Tanner, for a long period, would be to shut himself up in a close room, without change of air or exercise.

And similarly, when a person finds he cannot earn his living, or if he earns so little that he cannot get sufficient food to eat, he had better imitate the hybernating animals as nearly as possible, and get into some close, unventilated place, and lie down in perfect quiet and repose, and not fret at all, and he will then be able to exist on very little food.

On the contrary, when persons think they are able to earn their own living and a little more, and desire to live their lives, and enjoy thorough physical health and strength, the more pure air they breathe, provided they have an abundance of good wholesome food and plenty of exercise, the better and the greater will be the amount of physical or mental labour they will be able to perform.

The results of fresh air on the health of the army were most striking. The large mortality suffered by the army during the Crimean War led the Government to cause a careful examination of the barracks and military hospitals in Great Britain to be made, which showed that defective ventilation prevailed to a great extent. Numerous improvements were consequently introduced into barracks, and the following is the comparative mortality of the troops at home stations before and after these improvements in barracks had been effected. Before the improvements, the zymotic diseases amounted to 4·1 per 1,000 living; chest and tubercular diseases to 10·1 per 1,000 living; all other diseases to 3·7 per 1,000 living; and the total annual mortality to 17·9 per 1,000 living, or nearly double the mortality amongst the civil male population of soldiers' ages in England, which was only 9·8 per 1,000, although the soldier is specially selected after medical inspection as a healthy man.

After the ventilation of barrack-rooms and improved means of warming had been effected, and improved latrine and drainage arrangements and a better water-supply had been introduced, the deaths from zymotic diseases were only 0·96 per 1,000 living; chest and tubercular diseases only 4·20 per 1,000 living; all other diseases remained about the same, viz., 3·40, the total annual mortality being reduced to 8·56 per 1,000 living, a mortality, under the circumstances, still too high, and which, we may trust, will gradually diminish; but it is noteworthy that after the ventilation in the barrack-rooms had been perfected, an increase had to be made in the amount of the soldiers' rations.

Similarly, the older cavalry stables were low-roofed, with windows and doors at the ends; they were dark; there were no proper means of ventilation; the drainage was defective; the cobble-stone paving was in use, which could never be properly cleaned. The horses had, in short, no fresh air to breathe, and suffered from glanders, coughs, catarrhs, and other chest diseases. These older stables have been ventilated, and the paving and drainage improved as far as practicable. New stables have been constructed, on principles the reverse of the old. They have sufficient cubic space; they have abundant means of light and fresh air; the horses' heads are turned to the outer walls, and provision is made for fresh air being supplied to the horse while he is lying down; the paving and drainage have been properly constructed. Since then, glanders has scarcely been heard of, coughs and catarrhs have disappeared, and the horses are healthy.

It is unnecessary to multiply instances.

In speaking of carbonic acid, we have shown how comparatively uniform is the quality of air out of doors, and that great differences in the quality of air are shown from an analysis of the air in rooms. The impurities in air out of doors become rapidly dissipated in the surrounding atmosphere.

Dr. Leeds, of New York, says:—"There was quite an account made a few years ago of the wonderful cures of consumption that had been performed by the patient being removed to the stable, where he could be in close proximity with the cow; and I have no doubt many consumptive patients would find great benefit by such a course of treatment: not that there is any virtue in the smell of the cow, but that the air of the cow-stable would be nearer pure than that of their own chamber."

The reason why cities are so much more unhealthy than the country is

because the air in the streets is so much contaminated by the impurities which it is the practice to retain in and about the houses, on the street surfaces, and often on open spaces. It frequently happens that the whole subsoil of a town becomes saturated with impurities from carelessness in removing filth, and then that it gives out dangerous emanations. In many Indian cities nitre is obtained from the subsoil, which results from the surface having been long used as a deposit for excreta. The whole subsoil of our cities used to be perforated with cesspits, which were generally porous; and were so preferred, as rendering frequent emptyings unnecessary. The experience of Munich is most instructive on this question. In that city the enteric fever mortality, per 1,000,000 of inhabitants, for quinquennial periods was as follows :—

From 1854 to 1859, when there were absolutely no regulations for keeping the soil clean, and cesspits were porous	24.2
From 1860 to 1865, when reforms were begun by cementing the bottoms and sides of porous cesspits	16.8
From 1866 to 1873, when there was partial sewerage	13.3
From 1876 to 1880, when the sewerage was complete	8.7

This contamination of the air is specially important in most cities; and, indeed, in almost all old cities, because the houses are so built together that the vast ocean of air with which we are surrounded cannot get at and through the houses to purify them, as it does in the houses in the country. It is probable that a family living in the filthiest street in a city, if they were careful to have a constant current of air from that street, filthy as it is, passing through the house at all times, night and day, would be more healthy, other things being equal, than a family spending their winters in the finest house, if kept air-tight, in the healthiest location in the city, and their summer in the country, especially if they were always careful to exclude the *night air* from their bed-rooms.

This is fully borne out by the experience gained in London.

For instance, the average density of population of the metropolis is stated to be 42 persons per acre. But the crowded district of St. Giles has a population of 300 per acre, whereas Eltham has a population a little over one person per acre.

The death-rate of London, in a recent year, was 23·8 per 1,000; that of the district of St. Giles was 27 per 1,000; whilst the death-rate of Eltham was barely 17 per 1,000.

In these thickly-peopled districts there are narrow streets and courts; the houses are back to back, without any opportunity for the air to circulate between them, and therefore the impurities which necessarily float in the air of all occupied districts cannot obtain full exposure to the air, which alone can effect purification. Many instances can be given of the unhealthiness of confined districts. From the Report of the Select Committee of the House of Commons on the Artisan and Labourers' Dwellings Act, it appeared that in parts of Limehouse, where 514 persons were crowded into each acre of space, the death-rate was 50 per 1,000. as against 23 per 1,000 for the whole district.

But when sanitary conditions are carefully observed, the density of population affords no index of the death-rate. If, instead of covering an acre of ground with

houses two or three storeys high, without circulation of air between them, the same amount of population is accommodated in lofty buildings, say six or seven storeys high, with spaces in front and behind for the circulation of air, very different results follow.

Certain model lodging-houses, affording a density of 860 and 1,140 persons per acre, have yielded death-rates not exceeding from 16 to 18 per 1,000, which is owing entirely to the freedom with which the surrounding air is allowed to circulate around and through the buildings, and to the care exercised to remove every source of impurity from within the buildings and from the open surfaces retained around them. In addition to these considerations there is, in the use of lofty houses, also a benefit derived from elevation *per se*. The humidity at heights of above 50 feet from the ground up to 300 feet is less at night than nearer the ground. In clear weather and low fogs, between sunset and sunrise, the temperature at 50 feet is nearly always higher than on the ground or 10 feet from it. It will be found that at a height about equal to that on the upper rooms in a high house, a more equable temperature and drier climate prevails than at lower levels—drier than at the seaside, and with a daily range not much greater; and that it is less cold on the coldest and on foggy nights than down below. This experience may be summed up as follows—viz: Other circumstances being favourable, delicate persons should not sleep on a ground floor, or live in low situations; and living near the top of a high house and on the ridge of a hill might be of great benefit in many cases of lung and throat diseases, and in all cases where night air has a bad effect. The ground floor of all houses should be raised above the ground and well ventilated underneath, and houses, especially cottages, should never be considered habitable in which these precautions have not been taken. Moreover, in a thaw after hard frost, when colds and chills are frequent, fires are more necessary in lower rooms than during frost. It is also noteworthy that in frosty weather there must be some economy in admitting fresh air to a house from the upper part, where the air enters less cold than near the ground. It should be borne in mind that chills are more probable in low situations, and from draughts in lower rooms, about the time of sunset, than at higher levels; and that proximity to rivers, where extremes of temperature and damp mists occur, is most unwholesome for rheumatic and delicate persons. From these various considerations it should be recollected that for soldiers in time of war, and in all cases of camping out in the open air, it must be of great advantage to be raised a little above the ground at night.

CHAPTER XLIX.

Physical Properties of Air—Movement of Air—Diffusion of Gases—Standard of Admissible Impurity of Air in Confined Spaces—Hygrometrical Standard.

The first necessity is to obtain fresh air around our dwellings, and, having secured that, the object of ventilation is to enable us to assimilate the condition of air indoors as nearly as possible to that out of doors, so as to obtain in our dwellings a continual movement and change of air.

Before, however, explaining the methods by which ventilation can be secured, it is necessary to explain certain facts connected with the physical constitution of air.

Atmospheric air is governed by the laws which regulate other gases. Gases are perfectly elastic bodies. The elasticity of solids is within certain limits only ; the best springs of locomotive engines and carriages seem capable of enduring only a limited number of bendings before they break. Air remains constantly elastic. It has been shut up for years in the air-vessel of an hydraulic engine, and still exhibited this property as perfectly as at first. The volume is inversely as the pressure. As we remove the pressure, gases constantly expand, and always fill completely the vessel in which they are contained.

The specific gravity of air is regarded as 1 at the temperature of 32° Fahr., and with the barometer at 30·1 inches.

One hundred inches of air weigh 31,053 grains. Air is 14·25 times heavier than hydrogen, but water is 816 times heavier than air. The average pressure of the air on the surface of the earth and at the level of the ocean is equal to 15 lbs. to the square inch : that is, the air is capable of supporting a column of mercury of 30 inches, or 760 m.m., or a column of water of 34 feet in height. As we ascend, the pressure diminishes with the density, it being halved for every 3·4 miles. It follows, therefore, that whatever may be the extent of the air which surrounds the earth, one-half of the atmosphere must be confined to a distance of about three and a half miles from the earth. The velocity with which air enters a vacuum depends upon the height of the column of air above it : that is to say, at the level of the sea it will enter a vacuum much more rapidly than at the top of a mountain. Gases rush into a vacuum with a velocity inversely proportional to the square roots of their densities. The average temperature of the air in England is 60° Fahr. (15·50° C.). But this varies at different heights, the temperature decreasing approximately 1° Fahr. for every 300 feet in height. This rule is, however, subject to local variations.

The movements of the atmosphere may all be said to arise from differences of temperature. The molecules of air are but feebly attracted to each other, and small increases of temperature or slight diminutions of pressure separate the particles from one another, and thus one cubic foot of expanded air weighs less than a cubic foot of normal air. Similarly, small decreases of temperature bring the particles nearly together, and make the cubic foot of cold air heavier than the

standard above mentioned. This expansion and contraction are equal for equal increments or decrements of temperature. This increase of volume amounts to 0·375, or about three-eighths of the original bulk, in the process of being heated from the freezing to the boiling point of water; or a little more than $\frac{1}{491}$ for every degree of Fahr. If we wish to ascertain the volume which 100 cubic inches of air at 40° would occupy at 80°, we must remember that it does not expand $\frac{1}{491}$ of its bulk at 40° for each degree, but $\frac{1}{491}$ of its bulk at 32°. Now, 491 parts of air at 32° become 492 at 33°, 493 at 34°, and so on; hence, we can institute a proportion between the volume at 40° and that at 80°. For instance:

Vol. at 40°.		Vol. at 80°.		Cub. In.		Cub. In.
491 + 8	:	491 + 48	: :	100	:	108.

The expanded or lighter air moves up, and its place is filled by cooler, and therefore heavier, air, which takes its place. Hence, the upward movement of air depends upon its expansion by heat, because changes of density in the atmosphere produce an immediate motion of the heavier portions in their relation to the lighter.

Although other forces may have a limited influence, alterations of temperature are the great and efficient causes of the disturbance of equilibrium of the atmosphere; the solar heat warms the earth, which, in its turn, communicates heat to the air, and an upward current is immediately established. The alternation of day and night, and the revolution of the seasons, cause winds of a greater or less duration and extent. The ocean and the large inland seas or lakes are great and constant causes of motion in the atmosphere. During the day, the surface of the land becoming heated warms by its contact the air above it; the air, having thus become specifically lighter, is pressed upward by the colder and heavier air from the sea, which rushes in to restore the equilibrium. During the night, the earth, parting with its heat, becomes cool, and the sea being now the warmer surface, an upward current is formed over that, and an equalising current from the land arises.

In houses, the difference of temperature between the air of the house and that outside causes continual movement of the air.

When, as in winter, the air in a room or chimney is warmer than the outside air, an upward current takes place in the chimney. When, in summer, a chimney is colder than the outside air, a downward current takes place.

A

B

Fig. 200.

These movements all follow defined laws, which it will be convenient to explain in this place. If we have a tube, A B (Fig. 200), open at both ends, the point A will sustain the pressure of the superincumbent atmosphere, while the base, B, will sustain this pressure with the addition of that contained in the tube. As fluids press in all directions, the pressure upwards, under the base B, will also be the whole pressure of a column of the atmosphere above the level of B, upon the outside of the tube A B; consequently, if the air in A B be hotter and lighter than an equal column of external air, the pressure on B will be greater from below upwards than from above downwards, and the air at B will begin to ascend.

In the syphon A B C D E (Fig. 201), let us suppose the leg A B filled with a fluid equal in weight to the cold air, and the leg C E with a fluid equal in weight to the warm air; it is evident that if the fluid representing warm air is

lighter than the other, we must increase the length of the column, if we would have it balance the first; let this additional column be represented by D E. Now, if the end of the tube, A, be covered tightly with the finger, and the column D E removed, on lifting the finger, the fluid will spout from D with a velocity equal to that which a heavy body would have acquired in falling from E to D. This velocity, uninfluenced by friction or any other resistance, is eight times the square root of the height E D, nearly.

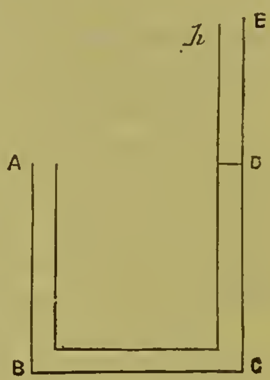


Fig. 201.

To ascertain the height E D, we measure with a thermometer the temperature of the atmosphere and of the heated air of the chimney, and multiply the height of the chimney in feet by the product of the difference in degrees between these two temperatures and the expansion for 1°; the result is the height of the additional column required to balance the column A B.

For example, let the chimney be 20 feet high, with the external air at 40°, and the temperature of the heated air 100°. Then 100° − 40° = 60°; 60° multiplied by 0·002036 (which is the expansion for 1°) = 0·1222, the expansion for 60°; 20, the height of the chimney, multiplied by 0·1222 = 2·44 feet, the additional height of warm air required to balance the cold air. Eight times the square root of this height, or 12·49 feet, is the velocity per second of the air ascending the chimney.

The rate of expansion is, however, not precisely what we have here given, because 491 parts of air at 30° have become 499 parts at 40°, and 559 parts at 100°; hence, we have a proportion between the parts at 40° and 100° by which we deduce the true expansion.

Vol. at 40°.		Vol. at 100°.		Height of Column.		Expanded Column.
491 + 8	:	491 + 68	: :	20	:	22·405.

The difference between the expansion by the first and second method is, in this example, but 0·039 of a foot, or about ·08 of a foot in the velocity per second—a quantity quite inappreciable in practice.

In the preceding calculation we have supposed that the only change which has taken place in the air of the chimney is expansion. This is not quite accurate where the chimney is carrying away the products of combustion. Other changes have taken place: the oxygen has been converted into carbonic acid, which is more dense than atmospheric air, and will consequently diminish the velocity of the ascending column. To arrive at more exact results, we must multiply the quantities of nitrogen and carbonic acid in 100 parts by their respective densities, add their products together, divide their sum by 100, and divide the above result by their quotient. But as the quantity of air converted into carbonic acid varies greatly with the management of the fire and other circumstances, and when one-half of the air, as usually happens, is consumed, the quantity by which the above result is to be divided is so very small that it may safely be neglected.

The movements of air which we have described are those which would be due to warm air uninfluenced by friction; but the results of calculations in which this is neglected differ widely from facts observed in practice. The resistance from

friction has been ascertained to be proportional to the length of the channel, to increase as the square of the velocity of the current, and to be in the inverse ratio of the perimeter of the channel. To obtain a correction for friction, then, we must have regard to the height of the flue or chimney, its diameter, and the velocity of the current; to these we must add a fourth cause of variation, depending upon the nature of the materials of which the flue is composed: for evidently a smooth surface would not offer so great a resistance as rough bricks or stones.

The formula according to which these corrections are made is somewhat complicated, but it is easy to see, from the above facts, that flues should be made large and with smooth sides. Moreover, as the same laws govern the movement of cold as of warm air, the air-trunks, whether for bringing cold air to the heating-apparatus or diffusing heated air in the apartments, should be as large, and the air move as slowly, as is consistent with the economy of heat.

Variations in the diameter of the flues must necessarily produce a change in the velocity of the air at the points at which the variations occur.

Thus, contractions in the flues are attended with an increased velocity, which augments with the diminution of the flue, so that it may be four or five times that due to the column of warm air. From the laws of the movement of fluids, it is a well-ascertained fact that all sudden changes are attended with a serious loss of velocity, which does not occur if the change takes place gradually. If the change is gradual, the loss is dependent upon friction alone. Whenever, therefore, we wish to contract the flues, it should not be done suddenly, but they should be sloped off gradually. If a flue be enlarged suddenly, as shown in Fig. 202, the result would be the formation of eddies, which would delay the flow of the air.

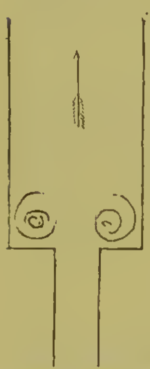


Fig. 202.

In connecting flues with a vertical shaft, it should be borne in mind that at the bottom the pressure of the atmosphere inwards is greater than the outward pressure of the gases contained in the chimney, that at the top the pressure may be from within outwards, while at some points between the two the pressure may be precisely in equilibrium. Consequently, independently of the advantage attending a longer column of warm air above, all subsidiary flues should enter as near as possible the base of the vertical shaft. Two currents entering at right angles may, if of equal velocity, destroy each other, or if of unequal velocity, the greater destroy the less. This should be prevented by giving all flues a vertical direction as they enter the vertical shaft. It is for these reasons that we so frequently find chimneys smoke when one flue is carried into an adjacent one.

If, for any reason, we wish to introduce a flue at a point where the inward pressure is slight, it can be done by contracting the vertical shaft suddenly just below the point of introduction, and by this means an inward pressure will be obtained. If, on the other hand, we wish to take air from a perpendicular hot-air trunk, we can do so most effectually by suddenly contracting the main trunk just above the opening.

Although the draught of a shaft increases in a certain proportion to the heat, still, it appears from calculation that this occurs only within certain limits, beyond which there is not only no increase in the draught, but a decided diminution.

The draught at first increases very rapidly with the temperature, but gradually

diminishing, it becomes constant between 480° and 570°, beyond which it diminishes, and at 1,800° it is less than at 212°. The reason of this is found in the great expansion of air at a high temperature, by which its volume is so much increased that, although the velocity may be very great, the quantity, when reduced to the temperature of the atmosphere, is less than at a low temperature.

The main point in the construction of a ventilating-shaft is to determine the dimensions required to withdraw a given amount of air. The velocity of the air escaping will depend upon the temperature, upon the height, and the diameter of the chimney.

In all arrangements of this nature we must be governed, in a great measure, by the expense; increase of diameter is the least expensive, then follows height, and a constant increase of temperature is the most expensive; besides which, we see from the above observations that this last can be carried to a certain extent only, while the two former have much greater limits.

Independently of the movements between the particles of air or of gases, aeriform bodies possess the property of diffusing themselves through each other's masses to an unlimited extent.

Hydrogen exhibits in a remarkable degree the power of diffusion: *i.e.*, a power due to the constant motion and mutual repulsion of gas-particles. If a bottle of hydrogen be connected vertically by a narrow glass tube with a bottle of oxygen, the oxygen (the heavier gas) being below, the hydrogen, against the action of gravity, will descend, and the oxygen will ascend, and a complete mixture of the gases in the two bottles will result. Similarly, if a vessel be divided into two parts by a porous diaphragm, one half being filled with one gas and the other half with another gas, diffusion will take place, until the admixture of the gases is complete. But the rate of diffusion is not alike. Graham's law is expressed thus:—" The diffusibility of two gases varies inversely as the square roots of their densities." Thus, the density of hydrogen is 1, and of oxygen it is 16, therefore the diffusibility of these two gases is as 4 to 1; in other words, the diffusion of four cubic inches of hydrogen will occupy the same time as the diffusion of one cubic inch of oxygen.

We can hardly estimate the importance of this law. Animals and vegetables, as we have already shown, are constantly pouring out certain gases, essential to the life and growth of the other; and yet, if these gases were allowed to stagnate where they are formed, they would not only injure, but destroy both the animal and the vegetable kingdom. But by this law of diffusion these poisons are diffused throughout space, and vital air rushes in to supply their place; and on account of this law, it is only by the most delicate analysis, and for a short time, that any differences in the constitution of the atmosphere can be detected.

Hence, the atmosphere performs the office of a universal solvent to the various effluvia which are constantly emanating from the surface of the earth, and from the substances and beings by which it is covered.

Moreover, as already mentioned, the atmospheric currents continually disperse the various impurities thrown into the air. The atmosphere is never stagnant. The air at the equator and between the tropics, expanded by heat, and urged by the colder atmosphere pressing from the poles towards the same points, rises, and diffuses itself through the upper air, and effectually prevents all stagnation.

The movement of the air is stated in the Registrar General's reports to be about twelve miles an hour, on an average, or rather more than seventeen feet per second. It will rarely be much below six feet per second.

Imagine a frame about the height and width of a human body, measuring about 6 feet by $1\frac{1}{2}$, or 9 square feet; multiplying this by the velocity of movement of the air at 6 feet a second, it will appear that in one second 54 cubic feet, in one minute 3,240 cubic feet, in one hour 196,400 cubic feet of air would flow over one person in the open country.

If it were desired to supply in a room a volume of fresh air comparable with that supplied out of doors, it would be necessary to change the air of the room from twice to six times in every minute, but this would be a practical impossibility; and even if it were possible, it would entail conditions very disagreeable to the occupants. It is thus evident that when considering the condition of air indoors, it is necessary to seek a standard of admissible impurity in the air rather than a standard of purity of air comparable with that which exists out of doors.

In judging of the amount of impurity which may be allowed in an inhabited air-space, the sense of smell, when carefully educated, affords the best indication of the relative purity and impurity of different kinds of air. The accompanying table, obtained from results of experiments communicated by Dr. de Chaumont to the Royal Society, shows the conclusions at which he arrived from a very large number of observations on the air of barracks and hospitals. The method employed in judging of the quality of the air was to enter directly from the open air into the room in which the air was to be judged, after having been at least fifteen minutes in the open air. It will be seen how closely the state of the room, as detected by the sense of smell, agrees with that which would be expected from the carbonic acid, as shown by analysis.

Sense of Smell.	Temperature.		Vapour.		Carbonic acid, per 1,000 volumes.	
	In air-space.	Excess over outer air.	In air-space.	Excess over outer air.	In room.	Excess over outer air.
Fresh	62·85	5·38	4·629	0·344	0·5999	0·1830
A little smell . . .	62·85	8·00	4·823	0·687	0·8004	0·3894
Close, or disagreeable smell	64·67	12·91	4·909	1·072	1·0027	0·6322
Very close, or offensive and oppressive smell .	65·15	13·87	5·078	1·409	1·2335	0·8432
Extremely close, when the sense of smell can no longer differentiate.	65·05	13·19	5·194	1·319	1·2818	0·8817

In these experiments, Dr. de Chaumont takes ·0002 of carbonic acid per cubic foot as the standard of impurity, in addition to ·0004 carbonic acid per cubic foot as the normal amount of CO_2 in the outer air.

The experiments were made in barracks and in hospitals, and a result comes out from them confirmatory of the opinion that in the case of sick men more air is required to keep the air-space pure to the senses than is necessary in the case of men in health. Thus, in barracks the mean amount of excess of carbonic acid, when the air was pure to the senses, was ·196 per 1,000 volumes, but in hospitals

it was only ·157; or, in other words, whilst in the hospitals the air would have smelt somewhat impure when the CO_2 was ·157, in the barracks with that amount it was fresh. This is, no doubt, caused by the fact that the emanations from the lungs and skin of sick persons are more loaded with offensive matter than those from healthy persons.

On these grounds it would therefore appear that whilst the standard for impurity for healthy persons may be regulated by allowing an excess of ·0002 per cubic foot of CO_2 over that in the outer air, it would be desirable to limit the excess in the case of sick to ·00015 per cubic foot.

In addition to the proportion of carbonic acid, and of the impurities of which its presence affords a rough test, there are conditions of temperature and humidity necessary for good ventilation.

Atmospheric air always contains more or less aqueous vapour, either in an invisible state or in the form of clouds, fogs, and mist. The form of vapour most commonly known is that of steam, which is vapour at the temperature of 212°, having an elasticity equal to that of the atmosphere, or thirty inches of mercury; this, however, is not the form with which we are now most interested. Vapour exists in the atmosphere at all temperatures, even below the freezing-point of water. Its elasticity at 32° is equal to supporting only $\frac{2}{10}$ of an inch of mercury. When the temperature of air cannot be diminished without depositing water upon the walls of the containing-vessel, or appearing as a mist, it is said to be saturated. If the temperature of saturated air be raised, it will, to the feelings, become drier, and will immediately begin to take up water which is exposed to it. Air is dry or moist not in proportion to the water it contains, but in proportion as it is more or less removed from the point of saturation.

The point of saturation rises more rapidly than the temperature. A quantity of air absolutely humid at 32° Fahr. holds in solution an amount of vapour equal to $\frac{1}{160}$ part of its weight; at 59°, $\frac{1}{80}$; at 86°, $\frac{1}{40}$; at 113°, $\frac{1}{20}$; and at 140°, $\frac{1}{10}$. Consequently, while the temperature advances in arithmetical progression, the power of the air to retain vapour rises with the accelerating rapidity of a geometrical series having a ratio of two.

The influence of this law is evident in the production of rain and clouds. When masses of air of different temperatures, each containing its full amount of aqueous vapour, mix, the result must be a deposition of moisture in one or the other of the two forms just mentioned. Suppose, for instance, the two masses of air be at 55° and 75°, the resulting temperature will be an arithmetical mean, or 65°; the force of vapour at 55° is 0·4327; at 75°, 0·8581; and that at 65°, 0·6146; the mean force is not 0·6146, but 0·6459, which corresponds to a temperature higher than 65°: consequently, a deposition of moisture must take place upon any cold surface the air meets with.

It is from this cause that steam appears as a cloud when escaping from the safety-valve of a steam-engine or the spout of a tea-kettle. The pressure of steam at 212° is greater than that which belongs to steam at the temperature of the air: consequently, the excess of vapour is deposited upon the bolder particles of floating matter in the air.

After continued cold weather, when our houses have been throughout reduced in temperature, and a warm moist wind succeeds, we perceive that moisture collects

upon the walls and furniture, or any other cold object; the cause of this deposit is to be found in the fact that the air in immediate contact with these objects is lowered in its temperature, and, being already nearly saturated, all the vapour above that due to this lower temperature immediately appears in the form of minute drops. A glass tumbler filled with cold water, in summer, is soon bedewed with moisture, because the air around it is cooled, and its moisture precipitated upon it; the same occurs in winter if the tumbler were brought into a close room in which many persons were assembled, and the air loaded with the accumulated vapour exhaled from their lungs and skins. From the same cause, the cold windows of a crowded lecture-room, in winter, not provided with efficient ventilation, are constantly covered with minute drops of water, which soon collect together, and run down the glass in streams.

The highest point of the thermometer at which vapour begins to be deposited by the air is called the *dew-point;* it is the point at which dew begins to form.

The humidity of the air is practically measured by the difference between the dry bulb and wet bulb thermometer.

In connection with this question, it is interesting to consider the relation which the sense of cold or warm bears to definite temperatures with varied proportions of humidity.

The natural heat of the body is being constantly supplied from the food and air we consume, and depends upon a constant loss of heat from the person, which has been calculated at from 3½ to nearly 6 units of heat per minute, the unit of heat being equal to one pound of water heated 1° Fahr.

The internal warmth of the body is 98° Fahr., and the feeling of comfort which is experienced under certain conditions of the atmosphere proceeds from the way in which the temperature and humidity regulate the cooling of the body. This cooling should occur with constancy and regularity, but not so fast as to produce cold. The heat generated in the body is lost partly in the air expelled by the breath, partly by evaporation of moisture from the skin, partly by conduction, and partly by radiation. The breath is inhaled at the temperature and humidity of the locality, but it is exhaled always at 90°, and is saturated with moisture at that temperature. It has been estimated that if the temperature of the external air were 62° and the dew-point 54°, there would be from about one-third to a half of one unit of heat in evaporating the moisture given out by the lungs and throat, and from one-tenth to one-sixth of one unit of heat in imparting heat to the exhaled air. Probably the amount lost by evaporation through the skin would bring up the loss from these causes to half the heat generated, leaving the other half to be dispersed in work, life, conduction to air, or radiation to other bodies. A moist atmosphere will check the insensible perspiration, but it will assist the loss of heat by conduction. A saturated atmosphere at from 35° to 50° Fahr. will be found to be intolerably chilly; and although the evaporation may be checked and this source of loss of heat removed, yet the conduction and radiation due to the vapour in the air will be enormously increased. A Scotch mist of 36° Fahr. (which is only super-saturated with vapour in excess at a slightly higher temperature than the air) penetrates clothing, and reaches every part of the person with penetrating cold.

A temperature of 50° to 65° in a nearly saturated atmosphere seems to provide

an equilibrium between the cooling action by conduction and radiation, due to the vapour in the air and the supply of heat from the checked evaporation from the skin, so that such an atmosphere is not uncomfortable, and is favourable to mental and physical exercise. It is said that this condition of atmosphere allows of the use of alcoholic stimulants, such as wine and beer, which would be immoderate in drier climates.

A temperature of from 65° to 80° Fahr., with a saturated atmosphere, becomes sultry and oppressive. The surplus heat cannot be removed by conduction or radiation, and the natural effort of the system is to produce evaporation. The least physical effort induces perspiration. The lassitude and enervation produced is unfavourable to mental and physical labour.

Above 80° Fahr. a saturated air becomes most oppressive, and it is questionable whether life could be prolonged in a saturated atmosphere of 90° or 100°.

All air may be considered dry at 35° Fahr.: that is to say, its capacity for moisture at that point is low.

Air which is used for ventilating purposes, and which is warmed in the process, has its capacity for moisture increased by the act of warming; and thus, in a cold damp atmosphere the air used for ventilation becomes comparatively dry when introduced into the room. On the other hand, in a dry cold atmosphere the air for ventilation, if warmed, may become too dry, and means should be adopted for adding moisture to it.

Similarly in hot weather, when air is required to be cooled, the moisture will be deposited by the cooling process, and means must be provided for again supplying it to the air in the room, in case it is found too dry as it is warmed.

Thus the rules which guide us in ventilation and warming in a climate like that of England are different from those which should be our guide in the United States or on the continent of Europe, where a much drier climate prevails; and the precautions for supplying the warmed air with moisture which are required in such climates are generally found unnecessary here.

In a ventilated room, the dry bulb thermometer in this climate ought to read 63° Fahr. to 66° Fahr., and ought not, if possible, to fall much below 60° Fahr. The wet bulb ought to read 58° Fahr. to 61° Fahr. That is to say, in this country the difference between the two thermometers ought not to be less than 4° Fahr. or more than 8° Fahr. A greater degree of dryness in the air, provided the supply of air be ample, is not, however, found objectionable. In the open air, in healthy weather, it is often 8° or 9°, or more.

Vapour ought not to exceed 4·7 grains per cubic foot at a temperature of 63°, or 5·0 grains at a temperature of 65° Fahr.: that is to say, the degree of humidity should not exceed 75 per cent.

CHAPTER L.

Volume of Air required for Ventilation—Confined Spaces—Conditions affecting Change of Air in Rooms—Draughts—Diffusion of Impurities in Air of Room—Floor-space—Cubic Space—Dependence of Ventilation on Temperature—Velocity and Temperature of Inflowing Air—Anemometers.

In considering the question of the volume of air which should be provided in a room to maintain a healthy atmosphere, it is interesting to show what are the requirements to which theory alone would bring us, and then to explain how that theory is affected in practice.

The sources of vapour inside the room are material elements to be considered. Every man gives off from lungs and skin each hour enough to raise the humidity from 70 per cent. to complete saturation in 500 cubic feet at 60° Fahr., and to raise it to 82 per cent. in 1,500 cubic feet. Now, to reduce this amount to 75 per cent. would take 3,000 cubic feet of air saturated at 50° Fahr., or 2,000 at 98 per cent. But the vapour given off by the body is not the only source of humidity. Humidity may arise from the vapour of liquids used in the room, or from the combustion of lights.

As regards the effect of the combustion of light on ventilation, much stress has been laid upon the greater oppressiveness caused by gas as compared with wax candles. From experiments made some years ago, comparing pure wax candles with ordinary 13-candle gas, it appeared that in 100 parts by weight of wax there were carbon 78·2, hydrogen 12·1, oxygen 9·7; whilst the analysis of gas showed that it contained carbon 72·1, hydrogen 26·4, oxygen 1·5, and that 1,064 grains of gas (or 5 cubic feet) gave as much light as 1,885 grains of wax; consequently the wax must have generated very nearly double the quantity of carbonic acid in producing the same amount of light. As a further experiment, the flames of several combustible bodies were burned in given quantities of atmospheric air, and the times noted at which the flames were extinguished by the contamination of the air, with the following results:—

Colza oil	71 minutes.
Tallow	75 „
Wax candles.	79 „
Spermaceti candles	83 „
13-candle coal gas	98 „
28-candle cannel gas	152 „

These numbers indicate that the atmosphere of a confined room, lighted by cannel gas, would require much less change of air to keep it pure, than a room lighted to the same extent with tallow candles. But the reason why people complain of the heat of gas compared with candles, is because they are satisfied with a dim light when they burn candles, but with gas they are not satisfied without a great deal of light, and therefore, in practice, the use of gas requires exceptional ventilation.

According to theoretical calculations, it would appear that, with an initial air-space of 1,000 cubic feet, occupied by one individual, it would be necessary to

supply 3,000 cubic feet per hour to maintain the room in a proper condition of humidity. As regards other impurities, if 0·2 per 1,000 of CO_2 are accepted as the limit of respiratory impurity in a well-ventilated air-space, in addition to the 0·4 per 1,000 in normal air, we can calculate out the amount of air necessary for the purpose; and from this calculation it appears that it requires 3,000 cubic feet per hour to preserve the air-space in the required state of freshness.

Thus the theoretical calculations, based first upon humidity, and secondly on carbonic acid, bring us to similar conclusions in each case; but in a warm climate the natural changes of temperature and consequent alterations of the conditions of the movement of air differ widely from those in temperate and cold climates. In such climates these figures may be applicable. The conditions of ventilation differ with each climate. Indeed it may be said that in each locality there are differences which affect, to some extent, the conditions of ventilation, arising from difference of site or of exposure; again, the conditions are affected by the arrangement, the material, and the mode of construction of buildings. It may be assumed that some of the difficulties which have arisen in solving problems of ventilation arise from the want of consideration given to these collateral circumstances.

From a careful practical examination of the condition of barrack-rooms and hospitals in this country, made by the Barrack and Hospital Commission in 1857–58–59, in which the degree of impurity of the air was tested mainly by the sense of smell, it appeared that arrangements which appear to provide for a volume of air much less in amount than that obtained by calculation will keep the barrack-rooms in a fair condition. These results have pointed to about 1,200 cubic feet of air per hour with 600 cubic feet of space. This need not be set down to errors in calculation or in theory. The conditions under which the air flows in and out of a room are so varied. The walls and ceiling themselves allow of a considerable passage of air, and especially unplastered walls, such as are in use in many barrack-rooms. It is difficult to find a building material impervious to air.

The following table shows the volume in cubic feet per hour of air which passed through a square yard of surface of equal thickness of the following materials, the pressure being obtained by a difference of temperature of 72° Fahr. inside and 40° Fahr. outside.

Sandstone	4·7 cubic feet.
Quarried Limestone	6·5 ,, ,,
Brick	7·9 ,, ,,
Limestone	10·1 ,, ,,
Mud	14·4 ,, ,,

It follows that a room with several of its walls exposed to the outer air would probably obtain more renewal of air by this means alone than a room with only one outside wall.

If a ceiling be observed, it will often be found that an old ceiling is blackened where the plaster has nothing over it to check the passage of air, and that where the joists come and the air has not passed so freely it is less black. If the plaster be broken it will be found that its blackness has arisen from its having acted like a filter, and retained the smoky particles while the air passed through. Moreover,

the porosity of the walls materially influences the moisture; for a porous wall may absorb much moisture.

In the close and confined dwellings of the poor the vapour collects on the walls and ceilings; it sinks into the walls, and gives that permanent loathsome odour which must be familiar to those who are acquainted with such localities.

In the absence of sufficient ventilation, when the walls are colder than the air, moisture condenses on the walls. On this account, rooms with walls of polished impervious material, filled with people, in which the walls are cold, would soon drip down with wet unless a very large amount of air be passed through them, so as to take up the deposited moisture. Such rooms would require a larger volume of air than the barrack-rooms experimented upon to keep them sweet.

Ill-fitting doors and windows allow of the passage of a considerable quantity of air. And in a temperate climate, where the changes of temperature of the outer air are rapid and considerable, especially at night, these means of producing the outflow from and the inflow of air into a confined space are in constant operation. A sleeping-room is very warm at bed-time; a rapid fall of temperature outside occurs, and at once a considerable movement of air takes place.

The majority of occupiers of sleeping-rooms in England close their windows at night; they often block up the chimney by a register or otherwise, to prevent the "blacks" falling. They have no special inlet or outlet for changing the air. In the morning they would, no doubt, come under Dr. de Chaumont's definition of "very close;" but if it were not for the continual insensible change of air which passes through the walls, doors, and window-chinks, &c., the occupants would be asphyxiated. A *well-built* house unprovided with special means for the inflow of fresh air is a real source of danger.

For these reasons the form of a building is important, especially where rooms have to be occupied by large numbers of persons: as, for instance, hospitals, workhouses, asylums, barracks, &c. In these a large surface of outer wall is advantageous, similar to that afforded in modern hospitals built on the pavilion principle. The reason of this is not far to seek. The air which thus insensibly comes in through the walls should be taken from pure sources. Thus asylums, hospitals, and barracks with outside walls, are better than those in which the rooms open out of a corridor or on each side of a corridor, because the air in a corridor becomes, after a time, saturated with impurities, and the interchange of air from it and the adjacent rooms becomes in time only an interchange of impure air. This is especially noteworthy in hospitals, where fresh air is of such great importance, on account of the great influence which the condition of the air exercises on the health of the patients. In private houses the question is of comparatively small importance, because the causes of impurity in the building are generally fewer than in buildings occupied by large numbers of persons.

In considering the question of ventilation, it is generally assumed that the impurities thrown out by breathing diffuse themselves uniformly through the air of a room. This is not strictly true. But upon this assumption, the degree of purity or impurity of air which is fixed as a standard ultimately in no way depends on the size of the room, but solely on these two things:—

(*a*) The rate at which emanations are produced.

(*b*) The rate at which fresh air is admitted.

The advantage of large space arises partly from the fact that the large room is longer in reaching the state of normal impurity than the small room. For instance, the following table shows the time required to bring air to the standard of admissible impurity—viz., 0·2 per 1,000 of CO_2, in different-sized rooms, in which all change of air is carefully prevented.

One man in	10,000	cubic feet,	3 hours 20	minutes.
,,	5,000	,,	1 hour 40	,,
,,	1,000	,,	20	,,
,,	600	,,	12	,,
,,	200	,,	4	,,
,,	50	,,	1	,,
,,	30	,,	36	seconds.

There is also the consideration that the inflow and outflow of air necessary to maintain the standard of impurity is less perceptible in a large than in a small room, for the chief difficulty of ventilation arises from the draughts it causes. Every one is professedly anxious for ventilation, but no one likes the fresh air to be admitted where it will impinge on them. There is, moreover, in practice, this advantage in the larger rooms: viz., that the larger wall-surface and the more numerous windows will allow of a larger passage of air through them, or insensible ventilation; and thus, with equal facilities for ventilation, large rooms will have an apparently less degree of impurity than small rooms.

Although the uniform diffusion of carbonic acid is very rapid in the air of a room, the organic emanations given out do not in practice diffuse themselves either rapidly or uniformly. They hang about in corners where there are obstructions to the flow of air, or near the ceiling. On this account efficient ventilation requires that there should be some space between the occupants of a room.

In living-rooms, however, the space between the occupants does not require so much consideration as in bed-rooms, because a certain space is necessary for moving about and for furniture; but in bed-rooms, and especially in nurseries or in rooms of that nature, occupied by more than one person, the question becomes of much greater importance.

For purposes of ventilation, the height must bear some relation to the size. Adequate movement in the currents of air cannot be secured in a room unless the height be proportioned to the width and length. Therefore, in proportion as the width and length of a room is increased so must the height be increased. In small rooms we should seek always to have a height of at least ten feet, because, as will appear presently, it would be difficult to change the air without inconvenience to the occupants with a much less height. In a very large room it might be necessary to give a height of 15 or 20 feet, so as to allow the currents of air to move freely. If the cubic contents of the room were taken as the measure of the number to be accommodated, the floor-space of the lofty room, 20 feet high, would be twice as crowded in proportion to a given area as the floor-space of the room 10 feet high. This would not be advisable. As, therefore, the height of rooms is very variable, it follows that it is rather the floor-space which must be considered in allotting accommodation to the occupants of a room than the cubic space.

In considering the question of floor-space in its aspect as connected with

ventilation, some guide is afforded by the rules laid down for barracks and workhouses, where economy had to be considered.

In barracks from 50 to 60, and under special circumstances, where the form of the building was defective or the surroundings were unhealthy, 80 feet of floor-space per occupant of the room are allowed.

In workhouses a minimum floor-space of 25 feet was laid down as admissible: that is to say, for each individual occupying the room, an area of 5 feet by 5 feet; but this was guarded by the proviso that very great care was to be bestowed on the ventilation. It would be better in nurseries and servants' rooms occupied by more than one person to approximate to the standard in use in barracks; and for dormitories in schools, less floor-space than from 50 to 60 square feet should certainly not be afforded.

In school-rooms which are occupied only in the daytime, or for a portion of the day, a smaller cubic space is sufficient. The reason is obvious: because the occupants leave the room empty occasionally, so that the air can be periodically renewed, and the students can begin each lesson with a reservoir of pure air.

Thus the proportion of floor-space and cubic space in any room must be regulated to a certain extent with reference to the conditions of its occupation, as well as to its form and capacity for ventilation.

The quantity of fresh air which it has been considered necessary in this climate to supply for each occupant of a room was laid down by the Barrack and Hospital Improvement Commission at 1,200 cubic feet per hour. This amount, with a cubic space per occupant of 600 cubic feet, allowed of the air of a room being changed twice in an hour. If the same inflow of air in proportion to the cubic space be supplied in hospitals, it would afford in the military hospitals nearly 2,500 cubic feet per occupant per hour, and in civil hospitals nearly 3,100 cubic feet per hour. Where rooms are more crowded, and the cubic space per individual consequently less, the quantity of air in proportion to cubic space should be increased. Thus, in a school-room where frequently not more than 200 cubic feet is allowed per occupant, which is a very unsatisfactory amount, the air of the room ought to be changed five times at least in an hour, if the room is continuously occupied for several hours. If, on the other hand, there are periods of intermission of occupation—that is to say, if the room is free after an hour's lesson, and the air is renewed so as to become fresh before the next lesson—a smaller rate of renewal during the limited occupation would suffice. But in all ventilating arrangements it is safest to provide for the maximum requirements.

Having thus explained briefly the general conditions which govern the movement of air and the amount of air to be provided, we will proceed to consider the various methods which have been adopted in order to give these considerations a practical application.

Ventilation may be effected :—

(1) By taking advantage of the ordinary currents of the atmosphere.

(2) By supplementing the effect of the ordinary current by generating heat in flues or chimneys, so as to cause movement.

(3) By direct propulsion of the air by fans or pumps, either to draw it into extraction shafts or to force it into the room.

The movement of air by the two first of the above methods is dependent upon

temperature, and all ventilation is intimately connected with difference of temperature. Hence, ventilation and warming must always go hand in hand.

The comfort of ventilation depends upon letting the air flow into a room at such a temperature, with such a velocity, and in such a position as will prevent the inmates from feeling any sensation of cold or draught. What is a draught? The explanation given by Pettenkofer is, perhaps, the clearest on this subject, and is as follows:—The unpleasant sensations from draught arise from a one-sided cooling of the body, or some part of it; this is frequently caused by a corresponding motion of cold air, but also in other ways, as by increased one-sided radiation, which occasions a local perturbation in our heat economy, and thus produces local consequences.

If a person perspires, and goes to the window with bared neck or chest, he feels a shiver not only there, but all over the body, and the perspiration becomes suppressed accordingly. The blood which at the time filled the blood-vessels of the glowing skin is displaced by the contraction of its channels; it is driven not only from the exposed parts, but from the whole surface towards the internal parts. If one or some of them are in a state of weakness, danger or bad consequences may ensue.

We hear often, "I don't like sitting near this window, close to this wall," and so on; "there is always a slight draught coming from there." We fancy that we feel in the draught the motion of a wind, but it is mostly the result of a loss of heat on one side by radiation towards the adjacent cold surface. People generally imagine in such a case that the wind is passing through the wall. But the velocity of such a wind would be too small to be felt as air in motion, and a piece of carpet fixed to the suspected wall, which checks the radiation of heat from the body to the wall, does away with the supposed draught. It could, therefore, not be caused by the air-rush through the wall, because the carpet is many times more permeable to air than the wall.

The velocity of the air as it flows in and out of a room, as measured at the openings for admission or exit, should not exceed one foot, or at most two feet, per second, for the following reasons, viz: first, in order to prevent a sensible draught being felt, and second, because a low velocity is favourable to the uniform diffusion of the incoming air through the air of the room.

To avoid friction, it is convenient that the velocity in the channels leading to the main extracting shafts should not exceed three feet to four and a half feet per second, and the velocity in the larger main extracting shafts themselves should not exceed from six to seven feet per second.

This latter velocity will, under general circumstances, and where the extraction is effected by means of a heated shaft, be obtained by a difference of temperature between the inside and outside of from 30° to 35° Fahrenheit. In special cases, on grounds of construction or otherwise, it may be found necessary to exceed this.

These velocities would be regulated by the size given to the inlets, outlets, supply channels, and extracting shafts, as compared with each other respectively, and with the quantity of air to be supplied and removed; which quantity would depend upon the number of occupants of the rooms to be provided for, and the amount of air to be allotted to each, and upon the number of lights burning, and other special causes of impurity in the air.

Air should, moreover, be introduced and removed at those parts of the room where it would not cause a sensible draught. Air flowing against the body, at, or even somewhat above the temperature of the air of a room, will cause an inconvenient draught, from the fact that, as it removes the moisture of the body, it causes evaporation or a sensation of cold.

Air should never, as a rule, be introduced at or close to the floor-level. The openings would be liable to be fouled with sweepings and dirt. The air, unless very much above the temperature of the air of the room, would produce a sensation of cold to the feet. It may be regarded as an axiom in ventilation and warming, that the feet should be kept warm and the head be kept cool.

The orifices at which air is admitted should be above the level of the heads of persons occupying the room; the current of inflowing air should be directed towards the ceiling, and should either be as much sub-divided as possible by means of numerous orifices, or be admitted through conical openings, with the smaller openings towards the outer air, and the larger openings towards the room, by which means the air of the entering current is very rapidly dispersed.

Air admitted near the ceiling very soon ceases to exist as a distinct current, and will be found at a very short distance from the inlet to have mingled with the general mass of the air, and to have attained the temperature of the room, partly owing to the larger mass of air in the room with which the inflowing current mingles, partly to the action of gravity, where the inflowing air is colder than the air in the room.

The velocity of the air may be measured or estimated in various ways. It may be measured by puffs of vapour of turpentine, or by balloons filled with hydrogen and weighted to be of the exact specific gravity of air, the time occupied by the puff of vapour or balloon in passing along a measured length being accurately ascertained.

For low velocities, it is worth noting that a sheet of light tracing-paper moved through the air at two feet per second takes up an angle of 45°, and affords a ready means of measuring that velocity; and for smaller velocities the angle assumed by the flame of a candle affords a fairly accurate index according to the following table.

Velocity of flow of air. Feet per second.	Angle of inclination of flame of candle with horizon.
1·6	30°
1·0	40°
0·75	50°
0·50	60°
·40	64°

In other cases, where the flow of the air is more rapid, an anemometer may be resorted to.

An ordinary form of anemometer is that of vanes fixed to a spindle, the revolutions of which are recorded by a counter. The vanes are turned by the direct action of the current of air, and the number of revolutions which are recorded by the counter gives the velocity. Of course the value of these revolutions has to be ascertained in the first place by direct experiment; that is, by forcing a known bulk of air through a channel of a given size, and ascertaining the number of revolutions made by the vanes, at different velocities, and thus obtaining the equation

for the particular instrument. Another method of ascertaining the value of the revolutions is to move the instrument itself through stagnant air at given velocities. It is necessary to measure the effects of various velocities, because, the number of revolutions corresponding to a given volume of air when the current of air is moving slowly does not necessarily correspond with the number of revolutions required to measure the same volume of air when the current of air is rapid. Moreover, the vanes will only begin to move after the current of air has attained a certain strength, and this form of measurement is therefore not applicable to very low velocities.

The most convenient apparatus for the purpose of measuring the relation between the motion of the vanes and the rate of the flow of air is a graduated vessel constructed on the principle of the ordinary gas-holder, from which a known quantity of air can be expelled at will through a channel of convenient dimensions in connection with it.

Fletcher's Anemometer is another very convenient form for measuring the speed of air in heated flues.

The instrument consists of two parts: the first part of two metal tubes of about three-tenths of an inch internal diameter, open throughout, and of any length; the second part of a manometer, or pressure-gauge. Of these tubes the end of one is straight and plain, while that of the other is bent to a right angle. When in use these tubes are placed parallel to each other, and so that their ends are exposed to the current of air to be measured (Fig. 203). They lie at right angles to the current, which thus crosses the open end of the one and blows into the bent end of the other.

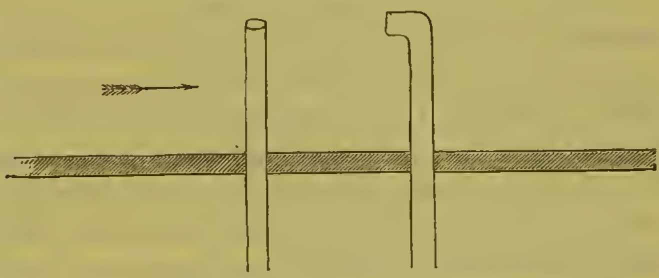


Fig. 203.

By this means a partial vacuum is established in the straight tube, whilst the pressure of the current forces the air into the bent tube; a differential manometer, attached to the outer ends of the tubes, shows the excess of pressure in the bent one over that in the straight one. The manometer used is a simple U tube of glass set vertically, containing ether, fitted with Vernier scales, by which the difference of level of the surfaces of the ether in the two limbs can be measured to $\frac{1}{1000}$th of an inch. This difference of level between the columns of ether becomes a measure of the speed of the current passing the ends of the anemometer tubes. The connection between the tubes in the chimney and the glass U tube may be conveniently made by means of india-rubber tubing.

CHAPTER LI.

Practical Methods of Changing Air by the Action of the Atmosphere—Effect of Temperature—Action of Wind—Sherringham's Ventilator—Vortical Tubes as Inlets—Shafts for Removal of Air—Tops of Shaft Outlet—Cowls—Watson's Ventilator—McKinnell's Ventilator.

We will now proceed to consider the action of ordinary currents of the atmosphere on ventilation.

The simplest way of obtaining a change of air in a room is to take advantage of the movement in the air produced by changes of temperature, or by the action of the winds.

In every room in which there is an opening at the upper part, out of which the warmed air can pass, and an opening either level with it or below it, through which fresh air can flow in, the system of ventilation by difference of temperature will operate.

Thus an ordinary sash-window is the simplest example. If the top sash be lowered and the bottom sash raised, the warmed air passes out of the room at the top, and the cooler outer air flows in below. Hence, for an inlet for air to an ordinary room, provided with a fireplace, but unprovided with special inlets, a very simple plan is to cut a slit at the lower bar of the upper sash of a window, so as to leave a clear space of about a quarter of an inch along its whole length, through which the fresh air will be drawn in in an upward direction. Or a piece of wood may be fitted to the bottom of the lower sash so as to increase its depth, and prevent its closing completely, thus leaving a permanent opening at the junction between the upper and lower sashes, without leaving any room for admission of air and draught at the bottom of the lower sash. The panes of windows are sometimes used for openings for air. One method is simply to cut holes in the pane of glass, and to fix another piece of glass in the pane, arranged on the principle of the hit-and-miss ventilator, by which the openings can be closed or opened at will. These are subject to the inconvenience of allowing a direct inflow of air, and consequent draught. In cottages there is often seen a tin whirligig inserted instead of a pane: this revolves with the admission of air, and breaks up and throws the current towards the ceiling. In window-panes the best forms of ventilators are those which direct the current of air towards the ceiling, such as hopper ventilators, or Moore's louvred panes; but all ventilators of this nature in windows are makeshifts; and it is preferable to adopt ventilation independent of the window-openings, reserving these for light, and for effecting a thorough change of air in the room at occasional times.

If a room has two outer walls on opposite sides, and if an opening be made in each wall, and if the wind blows against one of the walls, there will be an increase of pressure against that wall, and a diminution of pressure against the wall opposite, consequently air will be forced in through the inlet on the side against which the wind blows, and be extracted on the other side. In order to utilise this effect of wind-pressure, Sir Joshua Jebb ventilated barrack-rooms by hollow beams (Fig. 204), carried across the rooms from one outside wall to the other, communicating

with the open air at both ends, and also provided with openings into the room, but having a wooden partition placed across in the centre of the beam, so as to compel it to act both as an inlet and an outlet when the wind is blowing against either outer wall.

The action becomes more efficient if the beam be dispensed with and the

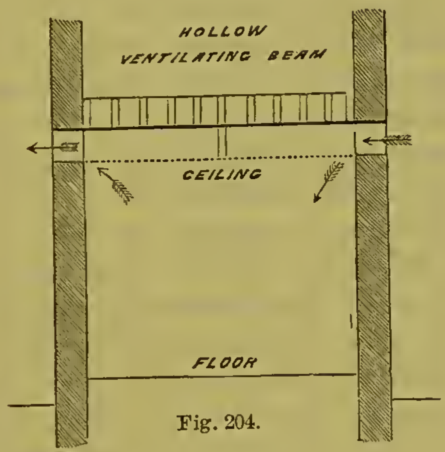


Fig. 204.

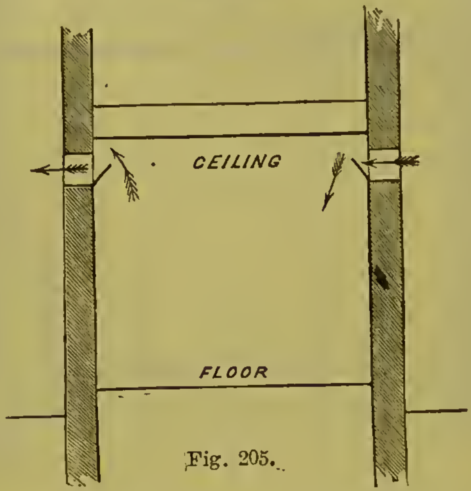


Fig. 205.

openings in the opposite walls retained (Fig. 205); the most convenient form for such openings is the Sherringham ventilator, or the conical ventilator above mentioned.

The Sherringham ventilator consists of an iron air-brick or box inserted close to the ceiling of the room (Fig. 206), and affording a direct communication with the external air. The current of inflowing air is directed by the hopper form of valve upwards towards the ceiling. The inside area is somewhat larger than the outside area, in consequence of the latter being closed with a grating, and thus the air enters the room at a less velocity than that at which it passes the outer surface of the wall.

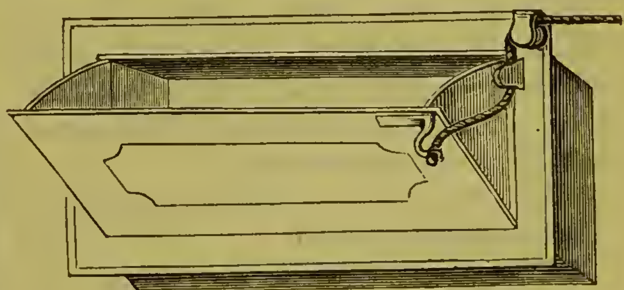


Fig. 206.

Inlets have been formed by vertical tubes, the opening to the outer air being made near the floor, and the tube being employed as a means of carrying the opening through which the air is allowed to enter the room to a height of five or six feet or more above the floor. This is convenient in cases where necessities of construction make it desirable to place the opening to the outer air low down, as compared with the point of entrance of the air into the room; or when it is desired to introduce fresh air into the centre of very wide rooms or halls without causing an unpleasant draught against the feet. The columns supporting galleries of halls or churches form convenient tubes, and the capitals may form the inlet to the room.

A system of this description has been in use in the British Museum for above twenty years. The fresh air is introduced by a vertical inlet placed between rows of opposite desks, and is admitted at a height above the level of the heads of the readers. The system has also been long used in coffee-rooms of hotels, and in dining-

rooms, pillars being placed in the centre of the floor, through which the fresh air flows, and passes out at a level of four or five feet or more, as the case may be.

Ventilating-tubes of this description have the advantage of directing the inflowing current upwards towards the ceiling; but in consequence of the friction of the sides of the tube, the velocity with which the air enters the room is less than it would be if it came in through a shorter channel and a more direct inlet inclined upwards. Therefore, in an outer wall a better effect will generally be obtained by a Sherringham ventilator.

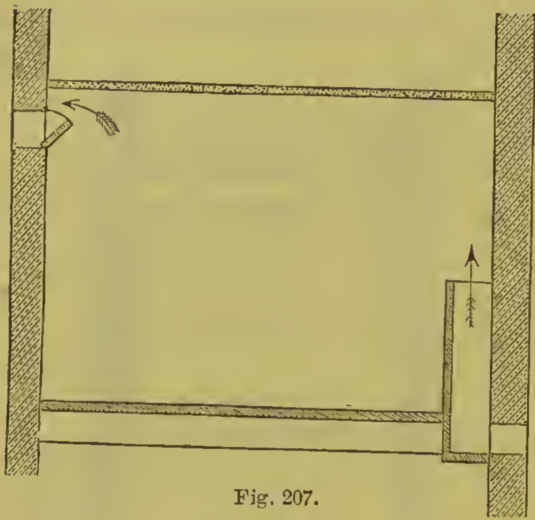


Fig. 207.

The main objection to these tubes (Fig. 207) is that they are difficult to clean, and hence they may become receptacles for dirt, insects, cobwebs, and dust, which after a time may injuriously affect the air passing through them. Moreover, inlets of this shape do not readily lend themselves to act the part of outlets when occasion requires, which is so convenient a feature of the Sherringham ventilator.

Upon the whole, Sherringham's, where applicable, is the more convenient form, and it is cheap and easily cleaned.

Where a room has two outside walls and is provided with openings on both sides, this inflow and outflow of air is almost certain to go on continuously, in consequence of the movement of the outer air, which is rarely at rest.

Where rooms have only one outer wall, other conditions prevail.

Under such circumstances, it may be desirable to carry a shaft from the ceiling to above the roof (Fig. 208). This is the principle of the arrangement adopted for barracks and military hospitals, combined with arrangements for warmed air.

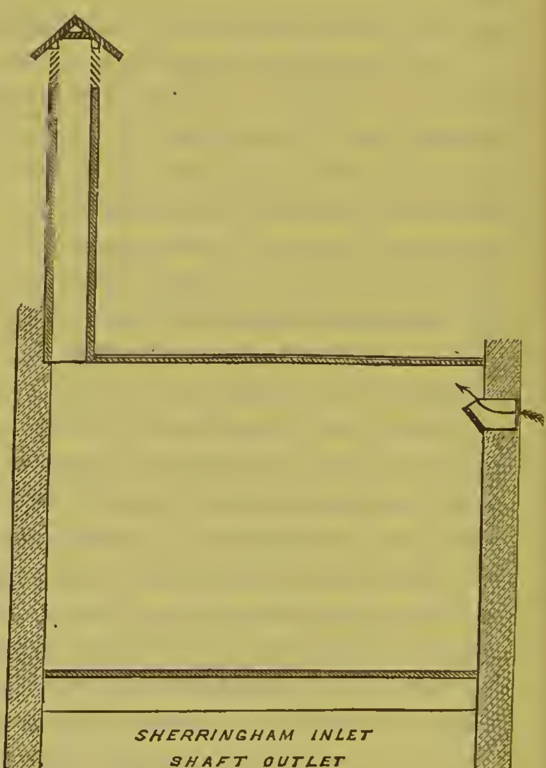


Fig. 208.

If an open tube or shaft be carried up from a room or enclosed space to a point above, where the top is exposed to the free movement of the atmosphere, an upward current will prevail in the shaft so long as there is a movement in the atmosphere, because the atmospheric current, in its passage over the top of the tube, relieves to a certain extent the pressure which prevails when the atmosphere is at rest, and thus causes the air in the tube to rise. The movement is, of course, unequal in its action. It is powerful when the

wind is high. In calm weather it is very small; but in this country, as already mentioned, the average velocity of the atmosphere is above 17 feet per second, and it is rarely quite at rest.

It is very difficult to measure the relation which the current in a tube or shaft caused by this method of extraction bears to the velocity of the wind, because there are so many conflicting elements to be considered. The formulæ for calculating the velocity of wind in some of the standard anemometers are not entirely satisfactory for the very low velocities, and it is in the case of the low velocities that it is most important to ascertain the current in the upward shaft, because in high winds the up-currents will, as a rule, be very strong. But the action of wind, whilst it tends to exhaust the air through the tube, is, at the same time, acting on all other openings in the building, either to exhaust or to force in air. Hence, gusts of wind will sometimes cause a reverse action in the tube, in consequence of some other opening acting temporarily as a means of extraction. It is often from this cause that chimneys are found to smoke in windy weather, especially when they are so constructed as to allow of a sluggish draught. The form of the top of the upright tube or shaft has an influence on the current in these cases. Thus, when the air which impinges on the flue is caused to slope upwards or sideways from the opening, it will frequently be found to prevent a reverse action or a down-draught.

Some experiments on this subject have been recently made by Lord Rayleigh in the Cavendish Laboratory, at Cambridge. The plan he adopted was to produce currents by means of a fan over the tops of variously-shaped tubes representing the top of a chimney. The following were the general results at which he arrived, and which he communicated to the British Association :—

The worst position for a flue is, as might be expected, near a dead wall, because the wind blowing against the wall causes momentarily a sudden pressure, which stops for the moment the escape of the gases up the flue. A current impinging on the top of the flue in a downward direction, at an angle of 30° or upwards, checks the draught; a current across the top of the flue, forming a less angle with the horizon than 30°, increases the draught; and the most advantageous effect is produced when the current strikes upwards at an angle of 30°.

A flue terminated with a T-shaped head, open at both ends, was very favourable against down-draught, except when the current struck down at an angle of 30° or more. But a T-shaped head, with two short, upright pieces at each end of the T, open at the top and bottom, was found to be an entire preventive of down-draught under all conditions of current. It must, however, be observed that such a form, even if it were proved perfect in a laboratory experiment, presents great inconveniences in practice from the difficulties in cleaning. Even if used for air only, it would tend to accumulate dirt, and smoke must inevitably clog it. The safest thing to do with chimneys is to terminate the chimneys, where possible, in a place where the pressure is not variable, and in any case to construct the chimney so that there shall be considerable velocity in the flue to counteract any temporary check from unequal pressure.

It must also be recollected that the temperature inside the flue, as compared with that of the outer air, has an important influence on the movement of the air.

If the atmosphere should be without perceptible movement in cold weather, when the temperature indoors is maintained for comfort above that out of doors,

the difference of temperature will cause an upward movement in the shaft. In hot weather, if the shaft is colder than the outer air, a down-current may ensue; but if, in hot weather, there should be little or no movement in the shaft, this occurs at a time when the windows can be kept open, and the air be renewed by this means.

The friction in the shaft varies inversely with the area, and with small tubes it forms a very perceptible element of retardation. Experiments made with tubes three inches in diameter tended to show that the velocity obtained in the tube was about two-fifths of that of the wind; larger diameters, on the other hand, produce better results.

In consequence of the numerous causes of disturbance enumerated above, this method of extraction, when applied to a house, could not be relied on to act on all occasions with certainty as an extraction-shaft; but it can be relied on to ensure in one way or other, and to a certain extent, a continual change of air.

Under similar conditions, it may be generally assumed that a tube or shaft with an open top will act satisfactorily. It is, however, necessary to protect the top, to prevent rain from entering the tube; but a cover may tend more or less, according to its shape, to delay the current in the tube or shaft. The shape of the cowl or top must be carefully designed so as to obviate this. The best form of cover or cowl would seem to be one which affords an opening larger in area than the area of the tube, the top of the tube being gradually enlarged on definite principles to suit the enlargement of the cover or cowl. A cowl with a curved head, arranged to move round with the wind, so as always to present its back to the wind, if gradually enlarged at its mouth into an oval shape, with an aperture a good deal larger than the tube, facilitates extraction. Buchan's and Boyle's cowls produce a similar effect, and have the advantage of fixed blades.

In connection with the extraction of air by tubes of this sort with the mouths turned away from the wind, there may be used other tubes with similar cowls turned towards the wind. This system is often used on board ships. The air is forced down the one tube and drawn up from the other.

There are certain forms of shafts which have been devised to act both as inlets and outlets, but in order to do so they require fixed conditions. Alter these fixed conditions, and any of them may become wholly outlet or wholly inlet. The condition essential to their operation is, that the room to which they are applied be closed, and in a closed room their action is singular. If a number of people be crowded into a room with the fireplace closed and the doors and windows shut, and if a tube of an apparently sufficient area to afford ventilation for the inmates be carried from the ceiling of the room to above the roof of the building, there will be an irregular effort at effecting an interchange between the air of the room and the outside air. The outer air will descend and the inner air will ascend, in fitful, variable, irregular currents, and the room will be badly ventilated, if ventilated at all.

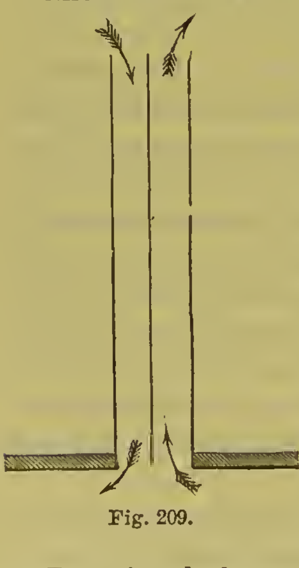


Fig. 209.

But, singularly enough, no sooner is the tube divided longitudinally (Fig. 209) from top to bottom by means of any division, however thin, than its action becomes

immediately changed—a current of air descends into the room continuously on one side of the partition, and a current of foul air ascends from the room continuously on the other side of the partition. One half of the tube supplies fresh air to the inmates of the room, and the other half removes foul air, so that if the size be properly adjusted the air in the room is kept sweet.

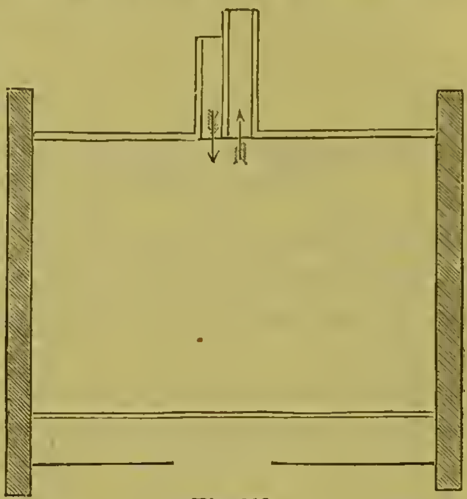


Fig. 210.

Watson's Ventilator (Fig. 210) supplies this principle in its elementary form. It consists of a square tube with a division down the centre, one side affording a tube slightly higher than the other: it has no means of diffusing the descending current. The annexed figure (Fig. 211) shows another form where the current is diffused. It is called M'Kinnell's Ventilator. It consists of two cylinders, one encircling the other, the area of the inner tube and encircling ring being equal. The inner one is the outlet tube; the casing of the other tube maintains the temperature of the air in it; and it is always made rather higher than the other; above it is protected by a hood. The outer cylinder or ring is the inlet-tube; the air is taken at a lower level than the top of the outlet-tube; when it enters the room, it is thrown up towards the ceiling, and then to the walls by a flange placed on the bottom of the inner tube, Fig. 211. Such a method of ventilation is very useful under certain conditions, but it is not universally applicable. Nor, indeed, is there any universal system of ventilation.

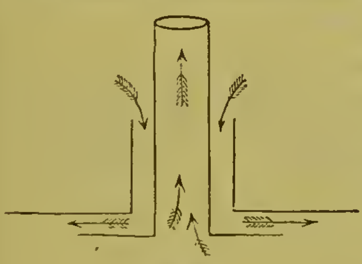


Fig. 211.

There is, however, one point in connection with all ventilation which cannot be too strongly kept in view—viz., that in ventilating a closed space, every inlet for fresh air requires a corresponding outlet, if movement is to take place. The excellence or the perfection of ventilation of a given confined space depends upon the relative arrangements for the inflow as well as the removal of the air.

CHAPTER LII.

Application of Heat for causing Movement of Air—Temperature of Compressed and Expanded Air—Condition of Combustion—Smoke—Radiant Heat—Conduction—Convection.

We will pass, in the next place, to consider the means of obtaining ventilation by supplementing the movement in the air by artificial heat. In order to make this subject intelligible, it is necessary to consider certain questions connected with heat.

It has been already explained that cool air is more favourable to breathing than hot air. This should be carefully noted as an axiom in ventilation and warming.

The act of compressing air produces heat; the corresponding expansion of air produces cold. The relation of the volume of the air to the heat and cold produced by compression and expansion will be best explained by a study of the following table, which shows approximately the cold produced by dilation and the heat produced by compression of air at different pressures. The volume at atmospheric pressure at the sea-level and at 60° Fahr. being assumed as 1·0.

Atmospheres.	Number of inches Mercury.	Volume of the air.	Actual temperature of the air during the process. (Fahrenheit.)	Difference due to compression or expansion. (Fahrenheit.)
0·5	15	1·634	—36·7°	—94°
0·83	25	1·137	+33°	—27°
1·000	30	1·000	+60°	0°
1·25	37·5	0·85	+94·8°	+34·8°
1·5	45	0·75	+124·9°	÷64·9°
2·0	60	0·61	+175·8°	+115·8°

Thus, if air at a temperature of 60° be compressed to half its volume, or to a pressure of two atmospheres, its temperature is raised to 176° Fahr.

The compression of the air caused by propulsion raises the temperature of the inflowing air. Some experiments of General Morin showed that in a system of ventilation where the pumping in of the air gave a pressure equivalent to 2 inches of water, the temperature was raised from 20° to 25° Fahr., between the temperature at the place from which the air was drawn into the fan and the temperature at the inlet into the room, notwithstanding the loss of heat which took place, viz., the absorption of the heat on the way.

If, on the other hand, air be expanded so as to occupy double the space, the temperature would be decreased to nearly 37° Fahr. below zero; and hence, if air be compressed, and if the compressed air be allowed to cool down to the temperature of normal air, and the air be then allowed to expand, a degree of cold will be produced equal to the difference between that caused by the compression and the

normal temperature. This affords an efficient means of supplying cooled air for ventilating purposes.

In connection with the question of cooling and warming air for ventilation, it should be noted that the mean temperature of the ground at a depth of from 10 to 20 feet is always much cooler than the summer temperature and much warmer than the winter temperature of the air; and that therefore a means of warming air in winter and cooling it in summer is to a certain extent always at hand.

In the original construction of a house ducts might be carried under the house to bring in the air, so that it would be warm in winter and cool in summer. A passage at a depth of 6 feet, of 200 feet in length, has had the effect of warming the air passing through it to much above the arithmetical mean between the outer air and that of the earth. But in any such arrangement it would be necessary that air-ducts, whilst being good conductors of heat, should be constructed of an impervious material, because the ground-air, or air which permeates from the ground, is liable to contain many deleterious matters. It is on this account preferable that the air so brought in should be brought in metal tubes. When such arrangements have not been made in the original construction of the house, simpler and less expensive arrangements may be made by sinking pipes underground, and drawing the air through them.

The efficiency of this arrangement would of course depend upon the proportion of the size of the pipes to the volume of air.

The air so brought in would be delivered in cold winter weather at a temperature which would require a much less amount of fuel to warm it than air brought direct from the outer air. It is also noteworthy that air drawn from a height of 50 feet from the ground would, especially where there are ground-fogs, be warmer than air drawn from close to the surface of the ground.

The next question to be considered in warming air is the heating-power of different kinds of fuel. This varies considerably, and depends chiefly upon the proportion of carbon and hydrogen which they contain.

In this country our heat is all derived from coal or the products of coal, such as coke or gas. Wood is only used as a luxury. The usual plan is to use raw coal; and, with all its imperfections, it is on the whole the cheapest and most convenient form of obtaining heat. There are, however, numerous objections to its use. It creates dirt and dust in a room; it sends up smoke and soot into the atmosphere; and, as we have already mentioned, makes our town fogs blacker and more persistent. Coke is free from some of these imperfections, and gas would be an eminently clean fuel. Dr. Siemens has proposed that, instead of burning raw fuel in our fireplaces, we should reduce our raw fuel into coke and gas, and then combine them in the fireplace. Gas made for illuminating purposes is, however, too expensive for a fuel. At 4s. per thousand cubic feet, it may be assumed to cost from three to four times as much as coal. But it is quite certain that if gas were made for heating purposes only, and were sold at from 1s. 6d. to 2s. per thousand cubic feet, the use of gas would obtain a very great extension, because it can be applied so conveniently and easily.

The oxygen required for combustion is supplied by air.

The nitrogen of the air passes through a fire without material alteration, and for purposes of combustion the oxygen alone is available. The nitrogen is indeed a

source of loss, because it has to be warmed in order to be carried up the chimney; and it would be a great source of economy in warming if some method could be devised of filtering the air, so as to allow the oxygen to pass through the filter and the nitrogen to be held back. Such a filter might be constructed of india-rubber, but the rate of passage of the oxygen would be too slow to admit of such a filter having any practical application. Baryta raised to different degrees of heat has been proposed for arresting the oxygen from the air and giving it out to the fire.

Experience shows that the air which has passed through a fire retains a considerable proportion of its normal quantity of oxygen, and therefore, for practical purposes of combustion, the supply of air should be increased beyond the quantity which theoretical considerations show to be necessary, in the ratio of $1\frac{1}{2}$ to 1 or 2 to 1. Thus, one pound of coal or charcoal may be assumed to require for its combustion about 300 cubic feet of air at 62° Fahr.; 1 lb. of dry wood about 160 cubic feet of air.

In a close stove perfect combustion depends on the area of the grate and other apertures for admitting air with reference to the fuel used, to the height of chimney or other means for drawing or propelling the air through the fuel, and to the power of regulating the inflow of air by dampers or doors. In open fireplaces, whilst a blazing fire will be best obtained by a grating under the fire, yet if the air be properly guided to the back as well as to the front and sides of the upper part of the fuel in an open fire, a bright fire will be obtained.

In all cases, when the supply of air is insufficient, carbonic oxide is formed. The formation of carbonic oxide in an ordinary grate in which coal is burned is shown by the blue-coloured flame which is sometimes seen, and is an evidence of an insufficient supply of oxygen at that part of the fire for supporting combustion.

The heat evolved in forming carbonic oxide is much less than that evolved in the formation of carbonic acid; therefore it is wasteful to burn coal with an insufficient supply of air, in such a manner as to allow of the formation of carbonic oxide instead of carbonic acid gas.

The effect of water in a combustible is to diminish the actual weight available for producing heat, as well as to absorb such a proportion of the heat generated as may be necessary for evaporating the water; therefore fuel should be as dry as possible. For instance, a fire supplied with damp wood will give out scarcely any heat.

We next come to the important question of smoke, which is the bane of all our large towns, and has been shown to have an important influence on the persistent character of fogs in large towns.

This question of the consumption of smoke has recently received considerable impetus from the serious fogs with which the metropolis was troubled two or three years ago, and numerous fireplaces were exhibited at the Smoke Abatement Exhibition, held in 1882, which had the object of preventing smoke.

Although elaborate experiments have been made from time to time with a view to ascertain the nature of the gases generated in furnaces, but little attention has been devoted to the composition of the gases given off from stoves and grates.

Amongst the earlier researches on chimney gases are those of Péclet, but his results, and those of some other experimenters, were open to the objection that the samples taken for analysis were only small fractions of the total gases in the

flues, and, were not taken with sufficient frequency to represent the mean composition. M. Scheurer-Kestner published in 1870 and 1875 the results of experiments made at Mulhouse, on the composition of the flue-gases of boiler-furnaces, which were more complete.

This chemist, in conjunction with M. Meunier, conducted a series of experiments, in 1868, on the combustion of fuel in boiler-furnaces, which showed the difficulty of burning fuel completely on the grate of a furnace; and the analysis of the chimney gases led to the conclusion that the products of combustion always contain unburnt constituents even with only a thin layer of fuel and an excess of air of more than 50 per cent., that is to say, with volumes of 15 cubic metres of air for every kilogramme of coal burnt, instead of 8 to 10 cubic metres. They also showed that the mean proportion of unburnt hydrogen reached 20 per cent. of the total amount present, which pointed to the fact that hydrogen is more difficult to burn, even under favourable conditions, than carbonic oxide, and that with a thin layer of incandescent fuel the unburnt carbon in the gas exists more often in the form of hydrocarbon than of carbonic oxide.

In the open fireplace much of the air in the flue does not come in contact with the fuel at all, and the dilution of the products of combustion by air varies with the rapidity of the draught.

In the experiments made by Mr. Chandler Roberts, F.R.S., for the Smoke Abatement Exhibition, which deserve careful study, the ratios by weight between the carbon completely burnt to carbonic anhydride, to that present in the form of hydrocarbons or carbonic oxide, varies between the limits of 1,000 : 8 to 1,000 : 259, ratios which are much higher than those obtained by M. Scheurer-Kestner, although they correspond with certain analyses made by M. Foucou on the gases escaping from the furnaces of locomotives. It would seem, therefore, that an open fireplace need not compare unfavourably (from the point of view of effecting the complete combustion of carbon) with the boiler-furnace, in which there is a larger mass of incandescent fuel; but it must be remembered that the appliances exhibited were in most cases specially designed for effecting complete combustion, and, further, that the stoking was in all cases effected with great care, so as to insure as favourable results as possible.

On the other hand, although in the case of the boiler-furnaces tested by M. Scheurer-Kestner the stoking was conducted with the most scrupulous attention, still the refrigerating action of a mass of water in the boiler must have impeded the union of oxygen and the combustible gases.

As regards soot, M. Delezenne estimated, in 1855, that the proportion of carbon that escaped combustion in the form of soot might be taken at 5 per cent. of the total weight of fuel burnt in the grate, and that 6,320 kilogrammes of soot fell in twelve hours on the town of Lille. But Emile Burnat, quoting Payen, pointed out in a paper on the combustion of smoke in boiler-furnaces, read before the Indus trial Society of Mulhouse, in 1875, that the amount of finely-divided carbon produced in a certain lamp-black factory is only 3 per cent. of the coal burnt, and therefore the amount of carbon in ordinary smoke must be much lower.

In 1858, Mr. John Graham estimated that very black smoke does not contain more than $\frac{1}{10}$ per cent. of the carbon of the coal burnt, and the experiments of M. Scheurer-Kestner already quoted showed that in boiler-furnaces the

loss of carbon in the form of soot never exceeds 1 per cent. of the fuel burnt, while the mean loss is probably between $\frac{1}{2}$ and $\frac{3}{4}$ per cent. A case, however, is recorded in which a coal containing 69 per cent of carbon (burnt with an inadequate supply of air) lost an amount of carbon as soot equal to 2·03 per cent. of the fuel burnt.

As might be anticipated, the amount of soot is greater in the case of an open fireplace than in a boiler-furnace, but the results of the tests made by Mr. Chandler Roberts at the Smoke Abatement Exhibition are not conclusive on this point, although they possess much interest.

In many cases the flues were carefully swept before and after the trial, and the soot was collected and weighed. In an extreme case, in an open fireplace, no less than $2\frac{1}{4}$ per cent. of soot, compared with the fuel burnt, was found in the flue at the end of the trial. In the case of three close stoves of careful construction, rather less than $\frac{1}{2}$ per cent. was found, while in some cases it fell to $\frac{1}{4}$ per cent., and in one case to $\frac{1}{20}$ per cent. But, on the other hand, these numbers do not include the amount escaping into the air.

In a preliminary experiment made with an ordinary open fireplace connected with a chimney by means of a sheet-iron pipe 6 feet long and 9 in. diameter, 17 lbs. of bituminous coal was burnt in three hours, and no less than 0·61 per cent. of the fuel burnt was collected in the pipe in the form of soot, while the soot that passed into the chimney was not collected. This 0·61 per cent. of soot, after drying at 100° C., yielded, on distillation at 300° C., 12 per cent. of an oily strong-smelling mixture of hydrocarbons.

The primary condition for the prevention of smoke is the complete combustion of the fuel; therefore the combustible gases should be intimately mixed with air, and the mixture should be effected at a high temperature. Those grates and stoves which fulfil these conditions in the most perfect way would be those which would develop most heat out of the fuel, and if their parts are properly arranged, they should give out most heat for useful purposes. They would also create least smoke. But in practice it has been found very difficult to combine these several conditions in an open fire.

Having thus described generally the conditions which govern combustion, we will proceed to mention the general character of the results to be obtained from the combustion.

Radiant heat passes through moderate thicknesses of air without sensibly heating the air, so that it may be assumed that air cannot be heated by the direct action of the radiant heat from a flame or an open fire; but the radiant heat warms the bodies which intercept the rays, and these bodies warm the air. For moderate temperatures the emission of heat from bodies by radiation is proportional to the difference of temperature, but for high temperatures and great differences of temperature, the proportionate emission is much greater. The radiant power of a body is equal to its absorbing power, and varies with the nature of the surface.

The passage of heat through a body by conduction varies directly with the quality of material and with the difference between the temperature of the inner surface exposed to the heat and the outer surface exposed to a cooling influence, and inversely as the thickness between the surfaces. Copper is a better material than iron for conveying the heat from the fire to water or air; and coverings of brickwork, wood, or woollen fabrics are better adapted than iron for retaining the

heat. The property which appears more than any other to make materials good non-conductors of heat is their porosity to air, and the fact that they retain air in their pores, air being a very bad conductor of heat.

In addition to the loss by conduction, the heat which has been communicated to a solid body is given out from it by radiation and by contact of cooler air; the rapidity with which it is thus given out depends, in the case of radiation, on the nature of the surface of the body; and in the case of loss by contact of air, on the form of the body only. The various modes generally in use of applying heat may be classed under open fireplaces, stoves, and hot-water and steam pipes.

CHAPTER LIII.

OPEN FIREPLACES.

Advantages of an Open Fireplace—Early Improvements—Permanence of General Form—Description and Results of Various Recent Grates.

An open fire warms the air in a room by first warming the walls, floor, ceiling, and articles in the room, and these in their turn warm the air. Therefore, in a room with an open fire, the air of the room is, as a rule, less heated than the walls. In this case the warming of the air depends on the capacity of the surfaces on which the rays impinge to absorb or emit heat; except that the heat received by the walls may be divided into two parts, one part heating the air in contact with the wall, and the other passing through the wall to the outer surface, where it is finally dissipated and wasted.

The open fire affords the simplest and most efficient form of outlet shaft for ventilation, because it both extracts the air from the room with great rapidity, and it causes a circulation of air; the method of heating by means of the open fireplace is also in accordance with that of the sun—the body is warmed, but the air remains cool; because the rays from the sun and the rays from a fire pass through the air without having much effect in warming it.

One lb. of coal is more than sufficient, if all the heat of combustion is utilised, to raise the temperature of a room 20 feet square and 12 feet high to 10 degrees above the temperature of the outer air. If the room were not ventilated at all, and the walls were composed of non-conducting materials, the consumption of fuel to maintain this temperature would be very small; but, in proportion to the change of the air of the room and to the escape of heat through the walls, windows, ceiling, &c., so would the consumption of fuel necessary to maintain that temperature increase. If the volume of air contained in the room above mentioned were changed every hour, nearly one lb. of coal additional would be required per hour to heat the inflowing air; so that to maintain the temperature at 10 degrees above that of the outer air during 12 hours would require 12 lb. of coal.

The principle of the ordinary open fireplace is that the coal shall be placed in a grate, by which air is admitted from the bottom and sides, to aid in the combustion of the coal; and an ordinary fireplace, for a room of 20 feet square and 12 feet high, will contain from about 15 to 20 lb. at a time, and, if the fire be kept up for 12 hours, probably the consumption will be about 100 lb.; or the consumption may be assumed at about 8 lbs. of coal an hour.

One lb. of coal may be assumed to require, for its perfect combustion, 160 cubic feet of atmospheric air; 8 lb. would require 1,280 cubic feet; but at a very low computation of the velocity of the gases in an ordinary chimney-flue, the air would pass up the chimney at a rate of from 4 to 6 feet per second, or from 14,000 to 20,000 cubic feet per hour; with the chimneys in ordinary use, a velocity of from 8 to 12 feet per second may indeed sometimes prevail, which would give an outflow of air of from 26,000 to 32,000 cubic feet per hour. This air comes

into the room cold, and when it is beginning to be warmed it is drawn away up the chimney, and its place filled by fresh cold air. A room 20 feet square and 12 feet high contains 4,800 cubic feet of space. In such a room, with a good fire, the air would be removed 4 or 5 times an hour with a moderate draught in the chimney, and 6 or 8 times with a blazing fire. The atmosphere of the room is thus being cooled down rapidly by the continued influx of cold air to supply the place of the warmer air drawn up the chimney; and General Morin estimated that of the heat generated by fuel in an ordinary open fireplace, about one-eighth only is utilised in warming the air of the room, and probably about two-eighths are absorbed by the walls, ceiling, floor, &c. &c., thus leaving about five-eighths to be lost up the chimney by imperfect combustion and other causes. The very means adopted to heat the room tend to produce draughts, because the stronger the direct radiation, or rather, the brighter the flame in open fireplaces, the stronger must be the draught of the fire and the abstraction of heat.

A fireplace is thus powerful enough to draw into the room all the air it wants; and for this purpose will use indiscriminately all other openings, whether inlets or outlets, if necessary.

The way in which an ordinary open fireplace acts to create circulation of air in a room with closed doors and windows is as follows:—The air is drawn along the floor towards the grate; it is then warmed by the heat which pervades all objects near the fire, and part is carried up the chimney with the smoke, whilst the remainder, partly in consequence of the warmth it has acquired from the fire, and partly owing to the impetus created in its movement towards the fire, flows upwards towards the ceiling near the chimney-breast. It passes along the ceiling, and as it cools in its progress towards the opposite wall, descends to the floor, to be again drawn towards the fireplace.

It follows from this that with an open fireplace in a room the best position in which to deliver the fresh air required to take the place of that which has passed up the chimney is above the projecting chimneypiece, and at any convenient point in the chimney-breast between the chimneypiece and the top of the room, for the air thus falls into the warmer upward current, and mixes with the air of the room without perceptible disturbance.

The open fireplace thus presents special advantages for securing efficient ventilation by means of the circulation of air which it creates. It makes the room in which it is in use independent of other means of extraction of air, unless the room is very crowded, or beyond the size for which the fireplace is calculated.

The air thus extracted must be drawn into the room from somewhere, and unless arrangements be made for supplying the room with warmed fresh air, cold air finds its way into the room through the special inlets, if they are provided; if not, through the chinks of the windows and doors, or wherever it can get in most easily. The large volume of fresh air required to supply that drawn up the chimney cannot always be warmed with sufficient rapidity by contact with the walls and furniture only; the temperature in different parts of the room is, therefore, frequently very unequal, and the occupants are subjected to draughts.

The only way to prevent draughts is to adopt means for providing fresh warmed air to supply the place of that removed. But the temperature at which the air is supplied must be regulated at the lowest point compatible with comfort—probably

in this country about 54° to 60°—or else one of the chief advantages of the open fire is lost.

There are many cases, in old houses especially, in which it is difficult to supply warmed air to the fireplace, or to make arrangements for its admission to the room.

In such circumstances the form of the grate of an open fire and its size in proportion to the room may materially affect the question of draughts, as will appear from the following considerations.

The effect of the open fireplace on warming depends on the radiant heat from the fire; this does not directly warm the air of the room; the rays from the fire warm the sides and back and parts adjacent to the grate; they warm the walls, floors, ceiling, and furniture of the room, and these impart heat to the air.

A fire with a bright flame, which therefore has a very high temperature, is under the most favourable conditions for emitting radiant heat.

The form and material of the fireplace, as well as the material of the surfaces on which the rays impinge, can thus assist materially the warming of the air. The rays should impinge more freely on the walls and floor than on the ceiling. A chimneypiece with a surface favourable to the absorption and emission of heat would be favourable to the warming and circulation of the air.

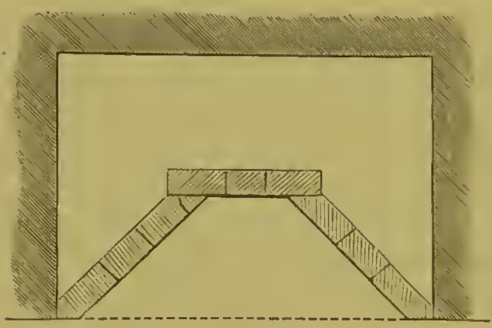


Fig. 212.

The nature of the walls and furniture will assist in warming the air. In an ordinary fireplace the sides should be splayed.

Count Rumford pointed out the advantages of splaying the sides and back of the fireplace in 1796. In those days large square fireplaces were in use. He reduced the large fireplaces by means of fire-brick sides and back. The accompanying plan shows the method he suggested (Fig. 212).

This system has been generally in use ever since, but in recent years our high art architects are gradually reverting to the old form of fireplace which Count Rumford's plans superseded. They make them artistic by the use of glazed tiles at the sides and back. This shape of the fireplaces is not calculated to afford the room the full benefit of the rays from the fire; but there is a great advantage in the sides and back being made of glazed tiles, because the enamelled surface emits the heat more rapidly than an iron or plain brick surface would do. If the maximum benefit is to be derived from an open fire in warming the air of a room, the sides and back of the fireplace should be of non-conducting material, with a surface favourable to the rapid absorption and emission of heat, and of such a shape as to radiate the heat freely, and especially to the lower parts of the room.

The size of the fireplace should be carefully proportioned to the size of the room, and the area of the chimney must be proportioned to the size of the fire and to the supply of air for the room. In order to enable it to act with the greatest degree of efficiency in producing a circulation of air in a room, the fireplace should be placed against an inner wall of the room; because the greater degree of warmth prevailing against the inner wall will cause the circulation of the air warmed by the grate and its surroundings to be more efficiently maintained.

If two fireplaces be placed in a room, they should, unless the room be very large, both be on the same side of the room, and if shafts are required for ventilating a room in addition to the open fireplace, they also should be placed on the same side of the room as the fireplace, but as far from it as possible.

By carefully attending to this matter, the inconvenience experienced from draughts caused by open fires may be much modified.

The most remarkable feature about the open fireplace is that, although, as a rule, we apply it in a form little removed from that in use 1,000 years ago, it has formed the subject of much invention. Mr. Edwards's very interesting book on fireplaces shows how much ingenuity has been exercised upon it. The outcome, however, appears to be that if raw fuel is to be used to warm our rooms, it is most convenient to apply it in the simplest way. And a simple form of fireplace which will with comparatively little trouble show a bright flame so as to afford radiant heat, and which will at the same time utilise some of the heat which passes up the chimney to warm moderately the air which supplies that removed by the chimney, and a grate which will at the same time produce only a small quantity of smoke, is the most desirable one to adopt, so long as we adhere to open fires. But if the growth of our cities is to go on as it has done during the last eighty years, we must, in the interests of the community, adopt, in our towns at least, some method of warmth which will not so completely destroy the purity of our air in the winter as the open fire does.

Meanwhile, it is interesting to consider the various forms of grates which modern inventors have devised, and we cannot do that better than by showing what the Smoke Abatement Exhibition produced in 1881 as the latest outcome of the question.

The grates at the Smoke Abatement Exhibition may be divided into the following classes :—

Class 1.—Open grates, having ordinary bottom grids and upward draught.
„ 2.—Open grates, having solid floors, adapted for "slow combustion," and upward draught.
„ 3.—Open grates, under-fed, supplied with fresh fuel beneath the incandescent fuel, with upward draught.
„ 4.—Open grates, to which fresh fuel is supplied from the back, or from the sides, or from hoppers.
„ 5.—Open grates, having a downward, or a backward, or a lateral draught.

This exhibition contained a very large variety of grates and stoves. A certain number of these grates were tested for temperature, smoke-shade, and consumption of fuel, by Mr. D. K. Clark; and, as already mentioned, the gases in the chimney were subjected to analysis by Mr. Chandler Roberts, F.R.S. The result of the testing was the selection by the judges of a certain number of these grates for awards.

The general principles which governed the awards are stated in the jurors' report as follows :—"In recommending the awards that should be made, we have considered that one of the chief essentials of a grate or a stove should be that no noxious fumes should be given off into the apartment; and another—in the case of open fireplaces—that there should be abundance of radiant heat. Subject to these considerations, we believe that apparatus to be most worthy of recognition in which the ratio of heating-power to the amount of smoke produced is the greatest. Other considerations are: combination of heating with ventilation; economy of fuel and

labour; simplicity of construction and of working; cheapness and durability; adaptability to existing arrangements; appearance; and these will doubtless influence purchasers considerably in their choice. But we are of opinion that—in determining our action as to awards in this—which is a Smoke Abatement Exhibition, and not an ordinary show of grates and stoves—these latter considerations should have small weight as compared with the main point of ratio of heating-power to smoke given off."

The experiments are of especial interest, as being almost the first experiments on a large scale where the various conditions of open fireplaces have been thoroughly examined, and we would commend the report to a careful study.

We have selected from the report of the Smoke Abatement Committee the more important tests made on the successful stoves, that is to say, those which received awards. These are shown in the following tables.

These statements show the general characteristics of the grates which were tested, viz., the fuel consumed, the heat given out, and the relative degree of smoke. The quality of smoke-shade is indicated by numbers increasing progressively from 0 to 10.

CLASS I.

Open Grates, having Ordinary Bottom Grids, and Upward Draught.

Name of Exhibitor.	Description.	Fuel Consumed.		Temperatures.			Chimney.		Chemical Tests.		Smoke-Shade.
		Coal per hour.	Ash.	External.	Average at walls 6ft. high.	Average difference due to Radiation 5ft. high, 6ft. from fire	Average velocity of draught.	Average Temperature.	To every 1,000 parts of Carbon as CO_2 there are of Carbon as $Cx\ Hy + CO$.	To every 1,000 parts of Carbon as CO, there are of Hydrogen free and combined with Carbon in the gaseous state.	Average.
		lb. oz.	lb. oz.	Deg. F.	Deg. F.	Deg. F.	Feet per min.	Deg. F.			No.
	Anthracite and Coke.										
M Perret.	"Radiating Stove," to burn anthracite. Back, sides, and floor of fire-brick: also a fire-brick slab to form a roof, sloped slightly upwards so as to assist in radiating heat. The grate consists of bars forming the bottom and the front.	2·0	1·6	44·0	48·60	15·63	316·31	259·09			0·79
M. Perret.	Same as above, burning Anthracite.	4·1¼	3.14	45·69	56·45	22·50	356·92	214·61	69	48	0·57
	Bituminous Coal.										
Rosser and Russell.	Fire-clay Stove. All of fire-brick, except a narrow section of the grate, forming the front part of the floor. The back is deeply fluted. The draught passes up in the flutes, and is reversed downwards behind the back of the grate, whence it is carried off to the chimney. Fresh air is heated within the fire-brick sides of the grate, which are hollow, and is delivered into the room.	3·6¼	0.9	42·50	66·54	19·90	430·0	195·56	39	52	1·92
G. Haller & Co.	The products of combustion pass up and down a number of large pipes grouped within a sheet-iron casing, into which fresh air is admitted. The air is heated and delivered into the room.	6·2½	0·9	38·0	57·32	19·73	430·0	187·50	84	—	3·00
E. H. Shorland.	"The Manchester Grate," G. L. Shorland's patent. An ordinary grate, with fire-brick lining. Narrow slit through back, 2 in. by ¼ in., for air to enter into the body of the fire. Fresh air is admitted from below, over the back and sides, which are gilled, and rises into two pipes to supply other rooms with warm air.	6·9	0·12	40·0	61·68	14·51	315·0	150·0	23	—	2·87

The Smoke Abatement Committee, in speaking of this class of grate, which may be said to include all ordinary grates, and in which the fuel is supplied at the top

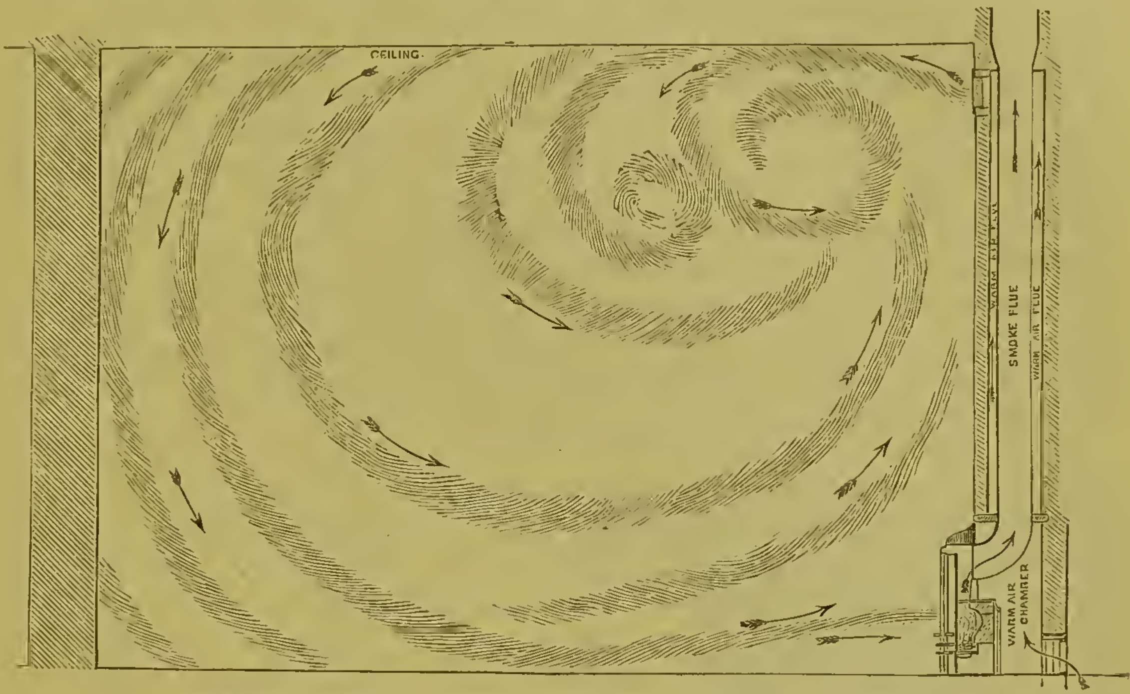


Fig. 213.—Galton's Grate, showing also the Currents of Air in a Room.

and the draught is upwards, say, "The grate devised by Captain Galton, R.E., about twenty-two years ago, for use in barrack-rooms, and adopted for that purpose

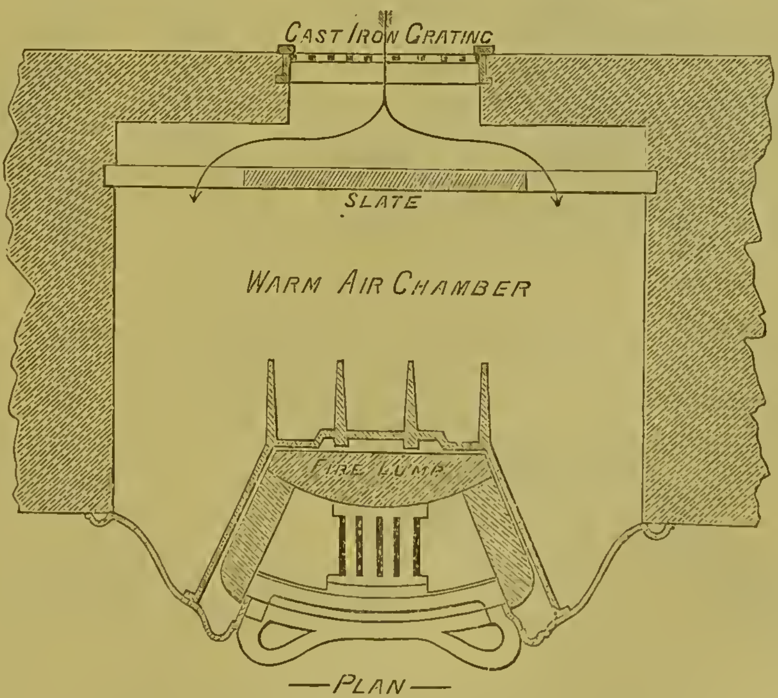


Fig. 214.—Galton's Grate.

by the War Office, deserves notice." The jury of the Smoke Abatement Exhibition add to their report that, "On account of the position occupied by Captain Galton,

with regard to the movement, this grate was not shown in competition, and was, therefore, not tested in the testing-house, which is unfortunate, as it might at least have served as a standard of comparison; and we believe it to be certainly one of the most effective of the grates in the exhibition." It is termed the "Ventilating Fireplace" (see Figs. 213 and 214).

In order to diminish the smoke, a portion of the air which feeds the fire is brought on to the top of the incandescent coal at the back of the grate after it has been warmed by contact with the hot fire-brick back. This forms a sort of baffle, which brings the warmed air into contact with the fire.

Fresh air is admitted from the outer air at the back, where it is warmed by a large heating-surface, and then carried by a flue, adjacent to the chimney-flue, to the upper part of the room, where it flows into the currents which already exist in the room. This fireplace preserves an equable temperature all over the room, and provides a large amount of fresh air, warmed, but not unduly heated.

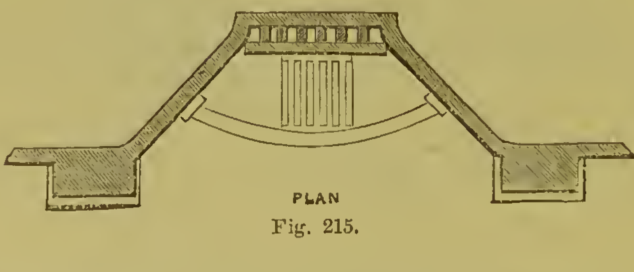
The following is the result of General Morin's experiments on this ventilating fireplace, showing the heat utilised on the air of a room in proportion to the fuel burnt; there would be in addition the heat absorbed by the walls, ceiling, and floor, which, assuming a cheerful fire to be maintained in both cases, would be much the same; and, as before mentioned, would amount in addition to about two-eighths, or ·25, of heat given off by the fuel.

Ordinary open fireplace.—Heat utilised on the air of a room = 0·125 of heat given off from fuel.

Galton's ventilating fireplace.—Heat utilised on the air of a room = 0·355 of heat given off from fuel.

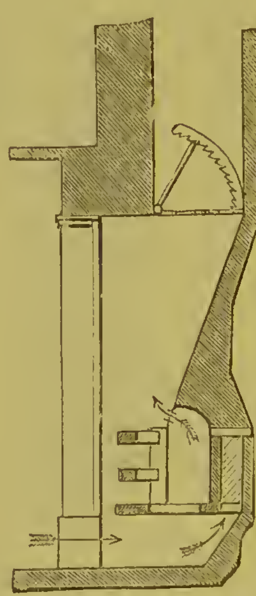
To produce the same degree of warmth in the air of a room, Galton's fireplace requires only one-third of the quantity of coal required by an ordinary fireplace, and whilst the total heat utilised in the ordinary fireplace experimented on by General Morin upon air, walls, ceiling, floor, etc., would amount to ·375 of that given out by fuel, the total heat similarly utilised by the Galton fireplace would be at least ·6 of that given out by the fuel.

The simplest form in which a baffle for compelling the gases from coal to mix with air in presence of the incandescent fuel is the one shown in the accompanying sketch (Figs. 215 and 216). The sides and back are



PLAN

Fig. 215.



SECTION

Fig. 216.

splayed, and of fire-brick with glazed faces. The cradle which holds the fuel is recessed about eight inches, as shown in the sketch. The back of the cradle is formed of a fire-brick slab with corrugations at the back. This slab rests against

the back wall, and the grooves caused by the corrugations form tubes through which air comes up at the back of the cradle which holds the fuel, and is deflected by the top of the recess on to the surface of the fuel. The air, being heated by contact with the face and flanges of the fire-clay slab at the back, is thus prepared to unite with the gases from the coal, and thus causes a bright flame. In order somewhat to check the combustion of the lower strata of fuel, the bottom of the fireplace is made of fire-clay, and is solid except for one-third of its area in the centre, which is provided with an iron grating.

This grating allows air to penetrate to the fuel at the back of the grate, and thus keep it in an incandescent state. The defect of solid-bottomed grates is that the fuel at the back cannot attain an adequate degree of heat to give off the gases at an adequate temperature.

The principle of admitting fresh air to a room warmed by a fireplace has been largely applied in recent years; and for old houses, where it is troublesome to cut

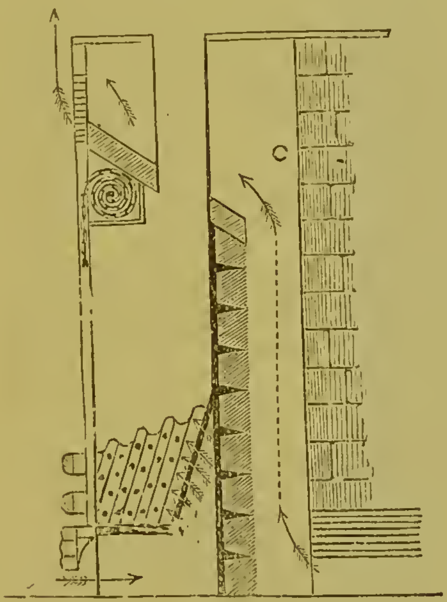


Fig. 217.

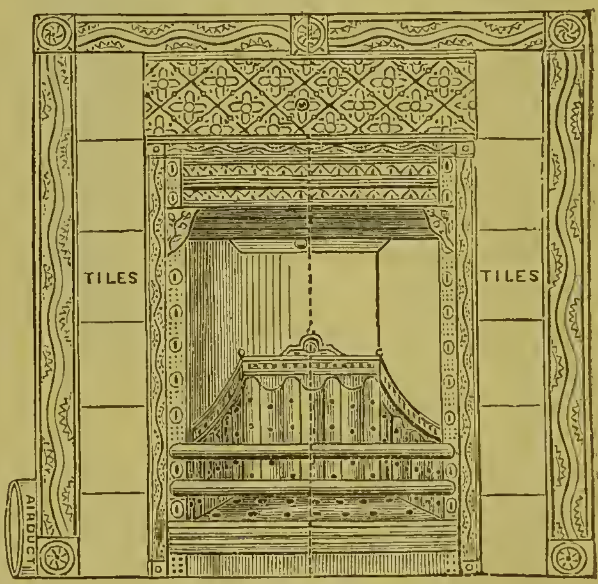


Fig. 218.

into the chimney-breast, the air must be brought into the room at the top of the air-chamber either below or just above the chimneypiece.

In cottages it can be done very efficiently by means of the grate used in barracks for married soldiers' quarters, which is described farther on.

In ordinary houses, where the cutting of the walls is inconvenient, the use of Griffin's grate (Figs. 217, 218) will be found to be advantageous.

In this grate the sides, back, and floor of the fireplace are of iron, perforated so that air enters into the fireplace on all sides. The back and flanks of the grate are of cast-iron, with shallow gills cast on the back surfaces, filled up flush with fire-clay to 1 inch in thickness. The roof also is coated with fire-clay. External air is admitted into a chamber, C, behind the grate, and is warmed, and then delivered into the room at the upper part. This grate is economical to fix, and it maintains a very even temperature in the room. Messrs. Boyd have long made a fireplace which warms fresh air, and which affords good results.

For fireplaces in the centre of a hall or ward, the one adopted in the Herbert Hospital is a convenient form. The chimney passes under the floor, and is placed in the centre of the flue, which brings in the fresh air which is to be warmed by means of the fireplace; by this means more than 36 superficial feet of heating-surface have been obtained for warming the air in addition to the heating-surface afforded by the air-flues in the fireplace; moreover, by this means the cold air first comes in contact with the less-heated part of the flue. The advantage of this arrangement is that the rate at which heat is communicated to the air by any heated surface depends upon the excess of the temperature of that surface above the adjacent air; and the temperature of the smoke-flue diminishes in proportion to its distance from the fire; therefore, by bringing the cool air first in contact with the coolest part of the smoke-flue, the latter conveys a larger proportion of its heat to the air than it would do if the air was warmed before it came in contact with the cooler part of the flue.

The fire stands in an iron cradle fitted to the fire-clay back and sides, and a current of air is brought through the fire-clay at the back, where it becomes heated, on to the top of the fire to assist the combustion, and thus prevent smoke. The top of the stove is coved inside, to lead the smoke easily into the chimney. The main body of the stove is a mass of fire-clay, with flues cast in it, up which the fresh air passes from the horizontal air-flue already mentioned, in which the chimney-flue is laid. Thus, all parts of the stove employed to warm the fresh air with which the fire has direct contact are of fire-clay.

This is especially essential in hospitals, where every element of possible impurity of air should be avoided. The sectional area of the fresh-air-flue with this arrangement of grate may be one square inch for every 100 feet of cubic contents of the spaces to be warmed, for favourable situations; but in cold or exposed localities a less area may be allowed.

The horizontal chimney-flue in the Herbert Hospital fireplaces is formed of two layers of sheet-iron, separated by a thin layer of fire-clay, so as to prevent over-heating of the surface, and it is about 110 square inches in area.

The horizontal chimney-flue terminates in a vertical flue in the side wall, which should be rather larger in area than the horizontal flue. This vertical flue is carried in the upper floors to a height of double the length of the horizontal flue, and is carried down to the basement, whence it can be swept. The points of connection between the horizontal chimney with the descending flue from the fireplace, and with the ascending flue in the wall, are very carefully rounded, as this is essential to assist the passage of the smoke. The horizontal flue is swept from an opening, to which access is obtained by taking up a movable board in the floor, and by pushing a brush along the flue, and thus forcing the soot into the vertical flue, whence it falls down and is removed at the opening in the basement.

There is placed a spare flue by the side of the vertical flue, terminating in a fireplace in the basement, which enables the vertical flue to be warmed, so as either to make it draw when the fire is first lighted, or to enable a current to be maintained for ventilating purposes through the fireplace when the fire is not lighted. The portion of floor over the horizontal flue should be so constructed as to be taken up in order to enable the air-flue to be easily and thoroughly cleaned

periodically. Fig. 219 shows a fireplace on a somewhat similar form, made by Messrs. Rosser and Russell.

Perret's grate, for anthracite, develops great heating-power and radiation, the tests showing that the combustion of fuel was fairly perfect. The grate is, as far

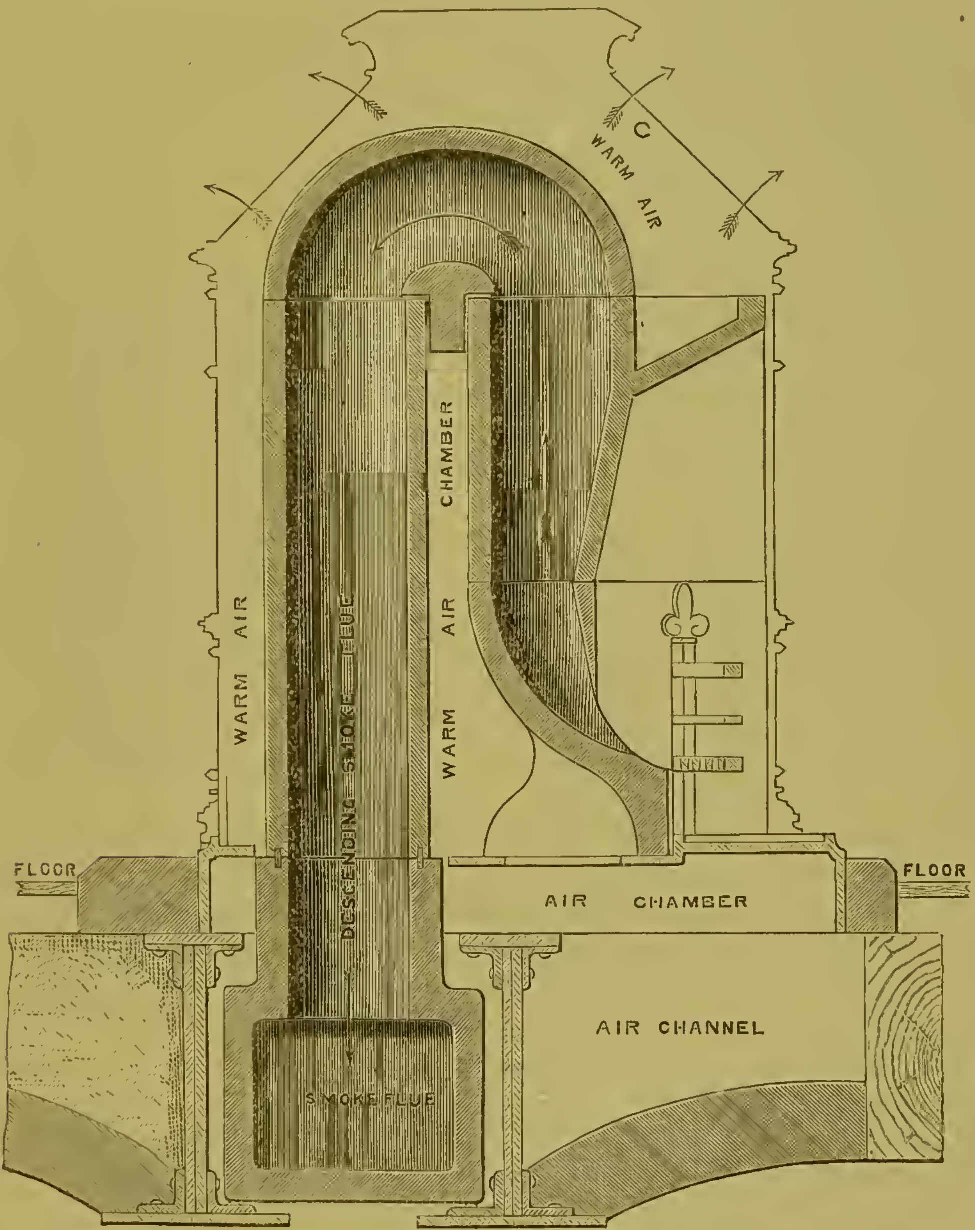


Fig. 219.—Rosser and Russell's Centre Grate.

as we know, a complete novelty. The recess of the fireplace is lined with fire-brick at the sides, back, and top, a narrow slit of 2½ inches wide being left at the front edge of the top for the escape of the products of combustion. The fire is made in an open iron basket-grate, set against the back of the recess, and supported on iron legs. The whole of the interior of the recess becomes very much heated, and there is a powerful radiation from it. A possible objection to this grate would seem to be that, under adverse circumstances, the products of combustion—apparently so

particularly irritating in the case of anthracite—might be diffused into the apartment.

The next class, very open grates with solid floors, is one which has obtained a large development in recent years.

Before proceeding to consider it, it may be mentioned that Mr. T. Pridgin Teale, of Leeds, has suggested an arrangement which retains the open grid; and, whilst checking the bottom draught, keeps up the combustion and retains heat better than a closed bottom to the grate. It is on the principle of the closed ash-pans. In advocating the arrangement, Mr. Teale remarks that the principle of slow combustion of coal in house fires depends upon two conditions in combination. One of these conditions is that no current of air should pass through the grate beneath the fire; the other was that the space or chamber under the fire should be kept hot by being shut off from the outer air. Others had made this discovery before him, and had embodied it in the construction of slow-combustion stoves; but, as far as he knew, nobody had taught the public how this principle might, at the cost of a few shillings, be beneficially applied to every ordinary house stove. Combustion could be retarded by cutting off the current of air which passed underneath the fire. This retardation of combustion had been attained mainly by three methods—first, by an iron plate resting on the grating and closing the slits against all passage of air. This method made a fire burn slowly, saved coal, but usually ruined the fire. The second method employed had been by the substitution of solid fire-brick for the open chamber beneath the fire. The solid fire-brick far surpassed the simple iron plate, as it became heated, and made a bright fire; but when the fire burned low the brick cooled, and the fire did not quickly revive when mended, and towards the end of the day the range became untidy from the accumulation of cinders and ash. In the third method, the space or chamber under the fire, and the open grating, were retained, but the chamber was shut in in front by a shield, or door, by which all current of air was cut off from the bottom of the fire, whilst the chamber itself was kept hot. Mr. Teale's plan is to place a shield resting on the hearth, and rising as high as the bottom bar of the grate, which forms a chamber closed from the air of the room, under the grate. He calls this an "Economiser," because of the saving of fuel it effects. It is perfectly simple, and can be applied to any ordinary grate. Mr. Teale says that in the ordinary grate the cinders, as they reach the bottom of the fire, cool down below their combustion-point, choke the grate with the ash, and in time put out the fire, unless the dead obstructive cinders are poked out and the draught restored. Whereas, by the use of the "Economiser," the bottom of the fire is kept hot, and the cinders remain at combustion-point on the iron grid until reduced to a fine ash, which drops through the bars, and thus the fire clears itself. The advantages which Mr. Teale claims for forming this heated chamber under the grate, which he calls an "Economiser," are—first, saving of fuel; secondly, more uniform heat; thirdly, the longer keeping in of the fire without watching; fourthly, the diminished soot, and fewer ashes to remove; fifthly, the cheapness of the arrangement, as it involves simply placing a sheet-iron shield under an existing fireplace.

It is to be regretted that this arrangement was not brought to notice for trial at the Smoke Abatement Exhibition.

CLASS II.

Open Grates, having Solid Floors, adapted for Slow Combustion and Upward Draught.

Name of Exhibitor.	Description.	Fuel Consumed. Coal per hour.	Ash.	Temperatures. External.	Temperatures. Average at walls 6ft. high.	Temperatures. Average difference due to Radiation 5ft. high, 6ft. from fire	Chimney. Average velocity of Draught.	Chimney. Average Temperature.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Carbon as C_xH_y + CO.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Hydrogen, free and combined with Carbon in the gaseous state.	Smoke-Shade. Average.
		lb. oz.	lb. oz.	Deg. F.	Deg. F.	Deg. F.	Feet per min.	Deg. F.			No.
	Bituminous Coal.										
F. Edwards and Son. (Manchester Exhibition.)	Dr. Arnott's Grate: Slow combustion. Fire is made up for the day on a grid, movable vertically by a screw motion. It is lit at the top, and burned downwards, and is elevated as required, so as to maintain one level of fire.	3·9	1·14	32·0	44·14	11·46	130·0	155·0	233	68	3·10
Jaffray and Co.	This grate is a modification of Ingram's Kaio-Kapnos grate. The back and sides are blocks of fire-clay. The floor also is of fire-clay, and is solid. The draught passes direct from the fire through the back, which consists of a number of upright slabs of fire-clay, having through air-spaces between them, resting on the floor and reared up against the back. The draught passes downwards towards the ash-pan below the floor-slab, whence it passes backwards through a perforated block of fire-clay into a flue which rises behind the back of the grate, and is enclosed with iron. The draught may be partially directed upwards through the register, dispensing with the backward movement. Stray gases rising upwards pass off, through two small openings at the upper part, into a flue at each side of the grate, downwards into the ash-pan, whence they pass through to the back flue. In passing through the perforated block, such of these gases as are unburned are likely to be consumed.	3·14¼	0·4	60·8	71·8	13 5	42·5	240·0	—	—	1·35
Doulton and Co.	"Tile Grate." Formed of fire-clay, on a fire-clay hearth. The fuel is laid on the hearth, guarded by a grid in front, which stands on the hearth, and can be placed in any position required. The back is sloped forward on the hearth. The fuel, piled up against the back, burns away mostly at the upper part, where the current of air strikes on the top of the fuel, on its way to the chimney. The heap of fuel partly projects into the room, and heat is radiated freely. The flanks of the fireplace are splayed, so as to further promote radiation of heat.	3·15½	0·14	42·0	66·71	12 75	291·0	144·0	48	70	1 33

The oldest form of these grates with solid floors is that of Arnott, which was proposed by him some forty years ago. In this grate there is a chamber which is filled with coal; the fire is lighted at the top, and gradually burns downwards; the bottom of the chamber is made to move up as the top layer is consumed; and all the gases which are distilled from the coal pass up, and, mixing with the air at the top, create flame.

At the Smoke Abatement Exhibition, the nearest to it in principle was that shown by Edwards and Son, in which the bottom of the grate is fixed, but the fuel burns downwards, and a counterbalanced shutter in front of the bars determines the level at which air is admitted to the fire, and consequently, that of active combustion. The results of the testing were, however, disappointing, as they showed that the fuel was not burnt to advantage, and a considerable amount of smoke was produced. The fault of the Arnott grate would appear to be that it does not

bring air to the back of the fire, so as to be in a position to mix with the gases at the back as they leave the solid fuel, and create flame; consequently, the Arnott fire is almost always a dull fire. Messrs. Barnard and Bishop's Glow Fire was intended to remedy this. It brings up a current of air from the ash-pit through a slit in the fire-clay, under a curved surface, or "baffle," arranged to throw the air on to the top of the fire. It would be of advantage if this air could be more highly heated on its arrival on the top of the fire, but this could only be done provided the principle of the solid bottom were somewhat departed from, and air allowed to pass to the coals at the back, so as to produce combustion at the face of the fire-brick back. Although not thoroughly satisfactory as a smoke-consumer, the grate was decidedly efficient, in that it caused a rise of temperature in the test-room of four degrees Fahrenheit per pound of fuel.

The next class is one which offers many advantages as a means of preventing smoke, because the gases from the fresh coal are compelled to pass through the incandescent coal, and, provided these gases are supplied with a sufficiency of air at a high temperature, the smoke would be prevented.

CLASS III.

Open Grates, under-fed: Supplied with Fresh Fuel beneath the Incandescent Fuel, with Upward Draught.

Name of Exhibitor.	Description.	Fuel Consumed. Coal per hour.	Ash.	Temperatures. External.	Temperatures. Average at walls 6ft. high.	Temperatures. Average difference due to Radiation 5ft. high, 6ft. from fire	Chimney. Average velocity of Draught.	Chimney. Average Temperature.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Carbon as $Cx\ Hy + CO$.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Hydrogen, free and combined with Carbon in the gaseous state.	Smoke-Shade. Average.
		lb. oz.	lb. oz.	Deg. F.	Deg. F	Deg. F.	Feet per min.	Deg. F.			No.
	Bituminous Coal.										
E. R. Hollands.	Under-fed Grate. A movable grid, to uplift the burning fuel, and make room for fresh fuel beneath it; after the fresh fuel is laid in, the movable grid is withdrawn, and the fuel settles down on the permanent grid.	2·9¾	1·0	43·52	57·84	13·20	370·0	134·80	103	67	2·52
Brown & Green.	"Smoke-consuming Register Stove." Fuel is placed on a shelf or sloping mouth at the front of the grate, level with the bottom, and is pressed into and below the fire by means of a flat-fronted utensil. The back of the grate is inclined forward at the bottom, so as to narrow the area of the grid, and cause the fuel to slide forward as it burns away. The back is slotted, to admit air to the fire. Behind the back there is an upright wall of fire-tile, by which the air at the back is warmed.	4·0½	2·1	31·0	53·02	21·46	430·0	137·50	32	41	2·12

Although the system of under-feeding appears to be generally effective in reducing the amount of smoke, it will be perceived that the character of the smoke-shade does not show such good results as might have been expected. The live coals are at the top, and therefore there is powerful radiation from them, which is not much reduced, as is the case in top-fed grates when fresh coal is put on.

Of the arrangements for direct under-feeding, that of Brown and Green appeared to be the best, from a practical point of view. Fresh fuel is supplied by being placed on the curved ledge which projects from the bottom of the grate, and it is

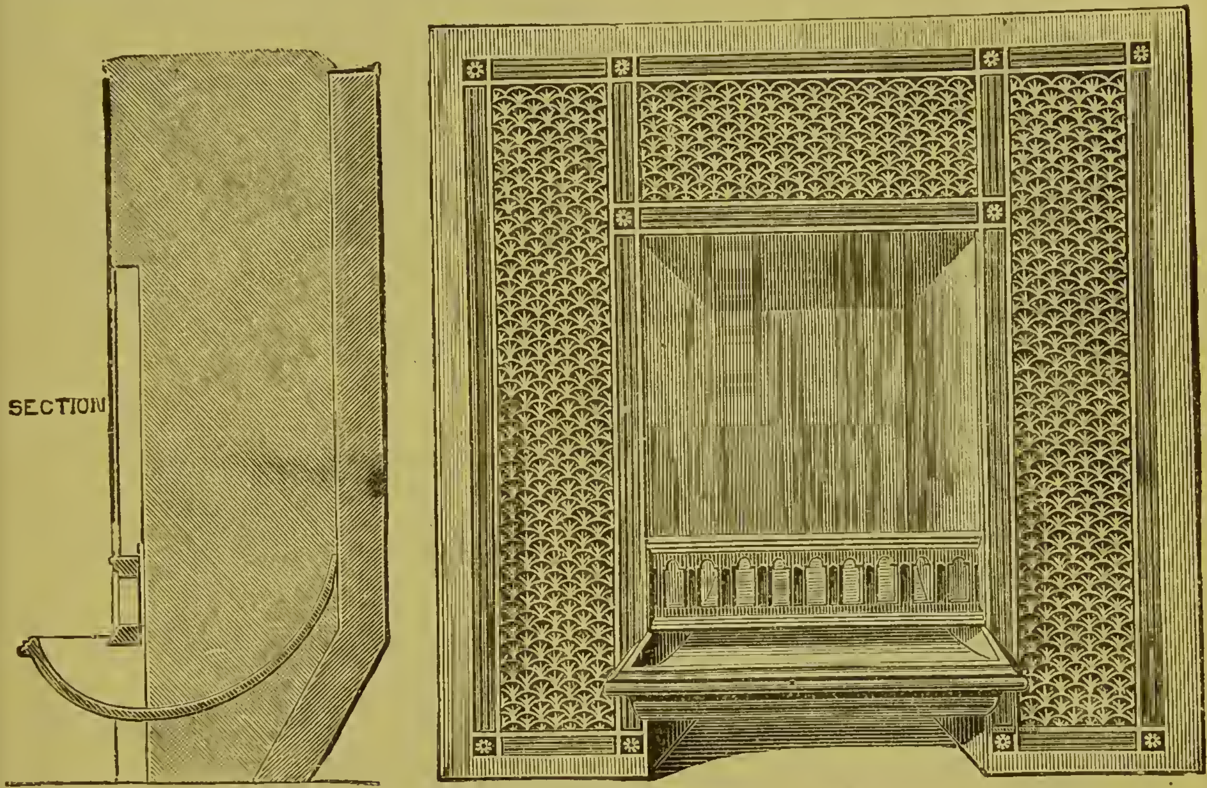


Fig. 220.—Brown and Green's Smoke-Prevention Grate.

then forced under the incandescent coal in the grate by means of a specially-constructed shovel; this grate also gave the best results of any of the grates which were tested at the Exhibition for bituminous coal. We annex drawings of this grate, Fig. 220.

There were other forms of underfeeding the fire exhibited. Amongst these may be mentioned taper shovels for supplying fresh fuel under the fire.

In connection with this mode of feeding may be mentioned Kaulbach's "Phœbus" Reversible grate. The basket is cubical, made of ornamental grating, admitting air to the fuel at every side. The basket is suspended on two trunnions, which are supported by carriages that travel on rails. Thus, the fire can be brought forward, or pushed back, and the temperature of the apartment regulated accordingly. A simple mechanical arrangement, concealed in one of the carriages, and consisting merely of a pinion and screw, enables the basket to be instantly reversed after re-feeding. The fire is lighted from the top and burns downwards, consuming its own smoke. The grate was submitted to a partial test, for smoke-shade; during the first hour there was no visible smoke, afterwards the smoke-shade varied from No. 1 to No. 2; and the average smoke-shade for the whole time of test, viz., three hours, was 1·13.

Somewhat similar in principle were the hopper grates, included in the following class. The best results were given by those of Hoole and of Stanley.

CLASS IV.

Open grates to which fresh fuel is supplied from the back, or from the sides, or from hoppers.

Name of Exhibitor.	Description.	Fuel Consumed. Coal per hour.	Ash.	Temperatures. External.	Temperatures. Average at walls 6ft. high.	Temperatures. Average difference due to Radiation 5ft. high, 6ft. from fire.	Chimney. Average velocity of draught.	Chimney. Average Temperature.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Carbon as CO, $Cx\,Hy + CO$.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Hydrogen free and combined with Carbon in the gaseous state.	Smoke-Shade. Average.
	Bituminous Coal.	lb. oz	lb. oz.	Deg. F.	Deg. F.	Deg. F.	Feet per min.	Deg. F.			No.
J. M. Stanley.	The grate is fed from a hopper at the front. The sides and back of the grate are of fire-brick. The gases are burned as they are distilled into the incandescent fuel below. The draught is carried through four openings at the bottom—two through the back, and one at each side—whence it passes through tubes or pillars, by which they are conducted into adjoining rooms for heating purposes. Fresh air is warmed behind the grate and delivered into the room.	5 6¾	1 0	45·0	68·92	10·0	348·0	323·0	19	16	2·24
H. E. Hoole.	"Radiating and Reflecting Grate." Coal is deposited in a small hopper at each side, forming hobs, and passes through an opening at the lower part of each hopper into the fire, occasionally assisted by the use of the poker. The fireplace is encircled by a polished reflecting surface of the form of a truncated cone.	2 2¾	0 4	33·0	58·80	14·60	180·0	157·78	78	79	2·55

Hoole's grate was decidedly the most efficient in radiating-power of all the grates in its class—owing to the excellent conical reflector, by which the heat radiated obliquely from the fire was effectively reflected into the room.

Amongst the other grates of this class may be mentioned that of Messrs. Musgrave and Co., termed the "Ulster Smokeless Stove Grate." The sides and floor are of fire-brick. A hopper is constructed at the back of the fire, to hold a supply of coals, which descends as it is burned away, and passes into the fireplace at the back, through a large opening at the lower part of the hopper. The fuel is loosened as required, and pushed into the fire by means of a lever. Fresh air is admitted at the back of the grate, and is delivered warm into the room. A perforated rolling curtain, made to slide up and down, acts as a blower, whilst permitting the fire to be seen through it.

We may also notice Archibald Smith and Stevens' grate, termed the Russell "Wonderful Grate," in which fresh coal is supplied from a hopper above the grate, at the front, passing backwards and downwards, and delivering the coal at the back of the grate. The grate stands forward, so as to present two open sides as well as the front, for radiation.

The next class is based on a principle the reverse of that of the underfed grates. This principle is to draw down the gases from the fresh fuel through the incandescent fuel which lies below, and then to pass the fumes into the chimney. It will be seen that the number of awards made to this class exceeded in number those

made to other classes; and as smoke-preventing grates there were some which presented a very high degree of efficiency.

CLASS V.

Open grates having a downward or a backward or a lateral draught.

Name of Exhibitor.	Description.	Fuel Consumed. Coal per hour.	Ash.	Temperatures. External.	Temperatures. Average at walls 6ft. high.	Temperatures. Average difference due to Radiation 5ft. high, 6ft. from fire.	Chimney. Average velocity of draught.	Chimney. Average Temperature.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Carbon as $CxHy + CO$.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Hydrogen free and combined with Carbon in the gaseous state.	Smoke-Shade. Average.
		lb. oz.	lb. oz.	Deg. F.	Deg. F	Deg. F.	Feet per min.	Deg. F.			No.
	BITUMINOUS COAL (*continued*).										
Clark, Bunnett & Co.	Ingram's "Kaio-Kapnos Grate," has fire-brick lining and floor. The gases pass through the back and downwards, and under the floor of the grate to the front; thence under a horizontal partition plate, to the back, and up the chimney. The draught may be partially or wholly carried directly upwards.	5 11¼	—	36·0	56·65	18·2	520·0	350·0	31	35	3·31
J. T. Reeve.	Reeve and Henry's Smoke Purifier. Hob-grate. The bottom grid is closed by a sheet-iron plate applied below it. The draught is direct, through slits in the back, into a filter bed or box containing iron turnings, which, becoming red-hot consume the smoke. The burnt gases pass to the chimney. A shallow chamber is constructed below the bottom plate, in which external air, admitted at the back, is warmed. The warmed air passes off into the room by side openings.	1 6¼	0 8	36·0	58·07	3·27	230·0	110·0	128	174	1·02
T. E. Parker.	The "Venecdor" downward-draught fire has a solid bottom, on a plate formed with gills. Air is admitted below the plate, passing between the gills, and is heated. It passes to the back, and meets incandescent fuel at the back angle of the fireplace, which is open there. The current passes into a back chamber of fire-brick. The stray gases passing to the upper part of the grate, are drawn down. The currents are united, and they pass off to the chimney.	3 7¼	0 3	33·0	61·72	11·36	270·0	180·0	7	8	2·20
Ditto.	The "Veucedor Grate," Same as above.	3 .2	0 3	34·0	57·47	12·09	330·0	156·70	44	60	2·37
M. Feetham & Co.	"Smoke-consuming Dog Grate," on the Hurst principle. Hollow gill-cheeks, with a nozzle at the back. Downward draught through the sides to the under side of the grate.	4 13½	0 4	38·0	69·22	23·21	530·0	182·0	213	34	1·19
	ANTHRACITE AND COKE.										
The Coalbrookdale Co.	"Kyrle Grate," Parker's patent. Fire-brick lining and floor. The draught is mostly downwards through an opening at the lower back corner into the flue. There is also a backward draught through an opening in the back, just above the fire, which meets the backward draught ascending from the bottom.	1 11¼	2 0	35·0	51·11	13·11	316·0	—	42	28	0·00
Yates, Haywood & Co.	Redmayne's Grate. Fire-brick sides, back, and floor. The draught passes horizontally through the back and sides, which are perforated, and it descends into a smoke-box below the floor; thence it passes up through pipes into the chimney. The pipes and the back are enclosed in a chamber, into which fresh air is admitted. The air is heated, and it passes into the room at the upper part.	3 11	—	47·0	71·39	15·35	289·05	195·45	49	59	0·27
Clark, Bunnett & Co.	Ingram's "Kaio-Kapnos Grate" has fire-brick lining and floor. The gases pass through the back and downwards, and under the floor of the grate to the front; thence under a horizontal partition plate, to the back, and up the chimney. The draught may be partially or wholly carried directly upwards.	4 15¾	5 0	37·0	53·36	13·0	330·0	200·0	16	41	0·00

Parker's "Vencedor" grate has an open front, and it stands clear of the chimney-opening, thus giving off heat to the room from the back, top, and sides, as well as the front.

Although the results of the testing of many of the grates exhibited in this class were satisfactory, the system appears to be wrong for open fireplaces. The upper surface of the coal in the grate, and the back and cheeks of the fireplace, are necessarily cooled by the draught, and can radiate little or no heat to the room, and the combustion of the gases takes place in a position from which no heat can be radiated into the room. The heat derived from this portion of the combustion must, therefore, be wasted, unless it can be utilised to warm air or water, and so be distributed. Moreover, there were instances in the exhibition where down or back-draught had produced rapid destruction of the bars, &c., of the grate; and, as so much of the combustion takes place out of sight, mischief may go on unnoticed.

The general conclusions derived from the experiments made on open fireplaces are summed up by Mr. D. K. Clark, and classed under the heads of Prevention of Smoke, Temperature, Radiating Power, &c.

From this summary it appears that Classes 1 and 2—*i.e.*, grates with upward draught—are least effective on the whole to prevent smoke, and that the grates with solid floors are less effective than those with an open grid for the admission of air below. Class 4—*i.e.*, grates fed by hoppers from the back or sides—is the most effective when the fresh fuel is very gradually distilled, and the smoke-making gases very gradually consumed. In Class 3 (under-fed grates), and Class 5 (down or back-draught grates), in which the gases are drawn upwards or downwards through the incandescent fuel, although no doubt the gases are at a temperature sufficient for complete combustion, yet the supply of air appears to be insufficiently mixed with the gases to complete the combustion. The following are the classes arranged in the order of smoke-shade :—

Class 2	. . . . . .	3·23 average smoke-shade.
" 1	. . . . . .	3·01 " "
" 3	. . . . . .	2·82 " "
" 5	. . . . . .	2·73 " "
" 4	. . . . . .	2·66 " "

It appears from this that the most effective grates for preventing smoke are the grates in which the fuel is supplied from the back or sides by means of hoppers; and that the grates with an open grid and upward draught are more effective, as a class, for preventing smoke, than grates with solid floors, termed slow-combustion grates. It is probable that the want of sufficient air at the bottom and back of the fire prevents the complete combustion of the coal in this latter form of grate.

Next in importance to the prevention of smoke is the degree of elevation of temperature in the room effected by the combustion of fuel in grates. The following comparative statement exhibits, in the seventh column, the average rise of temperature effected per pound of Wallsend coal consumed per hour, which is a measure of the comparative efficiency of the several classes of grates. The temperature at the six-feet level is taken as the standard rise of temperature in the room. In the sixth column is the excess of the average temperature maintained during the

test above the initial temperature of the room—at the commencement of the test. This is preferable, as a datum, to the external temperature given in the third column, for the external temperature exercises much less influence in determining the temperature that is maintained in the room than the initial temperature within the room, which is a measure of the heat lodged in the walls, floor, and ceiling.

Class. 1	Average weight of coal consumed per hour (Wallsend). 2	Average external temperature. 3	Average initial temperature in the room. 4	Average temperature actually maintained at a height of 6 feet. 5	Average equivalent rise of temperature. Total. 6	Per lb. of coal per hour. 7
No.	lb.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
1	4·32	42·3	47·2	58·3	11·67	2·88
2	3·37	41·9	47·1	55·0	9·64	2·99
3	2·91	37·5	45·0	54·7	10·39	3·81
4	3·72	39·3	48·2	58·5	10·37	3·05
5	4·04	39·2	48·3	60·4	12·10	3·38

The following shows the classes placed in order of the heating efficiency, as represented in column 7 of the table, beginning with the class of lowest efficiency :—

Class 1	. . . . .	2·88 degrees F. rise of temperature per lb. of coal.
,, 2	. . . . .	2·99 ,, ,, ,,
,, 4	. . . . .	3·05 ,, ,, ,,
,, 5	. . . . .	3·38 ,, ,, ,,
,, 3	. . . . .	3·81 ,, ,, ,,

From this statement it appears that, of the grates experimented on, those with ordinary fires, having bottom grids (Class 1) or solid floors (Class 2), are the least effective for warming the room relatively to the quantity of coal consumed per hour. Next in order are open fires feeding at the sides or the back, or from hoppers (Class 4). Then follow the grates of Class 5, having a downward or a horizontal draught; and lastly, as the most efficient of the open grates, those which are under-fed, with an upward through draught (Class 3)—one-third better than those of Class 1.

From these experiments it seems that open grates (Classes 3 and 5), constructed on the principle of drawing the combustible gases through the incandescent fuel, are the most efficient; and that, of these, the best are those (Class 3) which supply the fresh fuel below the fire, and cause the combustible gases to rise upwards through it.

The under-fed open grates (Class 3) are the only grates which are capable of continuously exposing a bright and open surface, unchecked by the presence of fresh coal, as well as of smoke, and unobstructed by special appliances; these grates therefore continuously expose a clear fire, from which heat should be continuously radiating, and from this cause it seems probable that the apparent excellence of the grates of Class 3 amongst other open grates is very much attributable to this distinctive characteristic.

A general correspondence may be observed between the smoke-shades and the efficiencies, as marked by the rise of temperature in column 7 of the foregoing

table: the efficiencies increasing as the smoke-shades are reduced. They are here placed in parallel columns for comparison, the order for smoke-shades being followed.

Class.	Average smoke-shade.	Average rise of temperature per lb. of coal per hour.
		Deg. F.
2	3·23	2·99
1	3·01	2·88
3	2·82	3·81
4	2·73	3·38
5	2·66	3·05

Here the efficiency increases generally as the smoke-shade is diminished. Excluding Class 5, their efficiency may be said to vary nearly inversely with the smoke-shade, that is to say, inversely with the imperfection of combustion as expressed by smoke-shade.

The total average radiations from the several classes of open grates varies generally in correspondence with the total average elevation of temperature. So also do the radiations and temperatures per pound of coal consumed per hour, though there were irregularities due to the varying circumstances of fireplaces.

Class.	Average weight of coal consumed per hour (Wallsend).	Average equivalent rise of temperature.		Average measure of radiation.	
		Total.	Per lb. of coal per hour.	Total.	Per lb. of coal per hour.
1	2	3	4	5	6
No.	lb.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
1	4·32	11·67	2·88	13·62	3·58
2	3·37	9·64	2·99	12·92	4·07
3	2·91	10·39	3·81	10·40	3·61
4	3·72	10·37	3·05	10·64	3·14
5	4·04	12·10	3·38	13·90	3·70

The relation between the smoke-shades and the observed radiations of heat may be gathered from the following parallel columns:—

Class.	Average smoke-shade.	Average measure of radiation per lb. of coal.
		Deg. F.
2	3·23	4·07
1	3·01	3·58
3	2·82	3·61
5	2·73	3·70
4	2·66	3·14

Here the radiations in general become less as the smoke-shades become less.

The following table shows the efficiency of anthracite in raising the temperature in comparison with the same classes tested with Wallsend coal :—

Class.	Rise per lb. of anthracite per hour.	Rise per lb. of Wallsend per hour.
	Deg. F.	Deg. F.
1	2·97	2·88
4	2·50	3·05
5	3·27	3·38
Average . . .	2·91	3·00

The average of the three classes of open grates, 1, 4, and 5, is nearly the same for anthracite and Wallsend. But the anthracite has the advantage for ordinary open grates in Class 1. Moreover, this table appears to show, as might be expected, that anthracite is found under more advantageous conditions in grates to which a considerable supply of air is afforded. Thus, the grates in Class 1 which have an open grid below, and the grates in Class 5 where a supply of air is drawn down through the fuel from the top, both show a better result than grates of Class 4, where the air does not have such consequent access to the fuel.

The following is a comparison of the measures of radiating force for anthracite and Wallsend coal :—

Class.	Radiation per lb. of anthracite per hour.	Radiation per lb. of Wallsend coal per hour.
	Deg. F.	Deg. F.
1	2·64	3·58
4	2·71	3·14
5	4·22	3·70
Average . . .	3·19	3·47

The radiating force attains a maximum in Class 5 of open grates, with downward or backward draught, for both kinds of fuel.

The difference of heat appears to be as much affected by ordinary circulation of air in the room as by the employment of special means of inducing circulation and ventilation. But there were marked differences in the variations of temperature in the room at various levels between the air-heating and the non-air-heating grates and stoves.

It appeared that the uppermost part of the room heated with open grates was much warmer—by as much as 9° in most instances—than the lowermost parts. It also appeared that the employment of means of introducing warmed air into the apartment, and of ventilating it, was not necessarily influential in reducing inequalities of temperature at different levels. In some cases it appeared, on the contrary, to augment the actual difference that arises when no special ventilating and warming contrivances are provided. This seems to depend on the volume of fresh warmed

air, on the temperature at which it comes in, and on the place where introduced The results of the tests at the Exhibition are shown in the accompanying table.

Class.	Air-heating and Ventilating Grates.			Non-air-heating Grates.		
	Temperatures at the following levels above the floor.			Temperatures at the following levels above the floor.		
	6 inches.	6 feet.	14 feet.	6 inches.	6 feet.	14 feet.
No.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
1	54·1	59·3	63·4	53·0	56·1	57·5
2	52·0	53·5	52·9	52·7	56·1	57·7
3	49·9	54·6	58·3	—	—	—
4	51·0	56·1	58·1	54·0	59·0	63·5
5	56·2	61·7	65·4	52·4	56·6	59·4
Average . .	52·6	57·0	59·6	53·0	56·9	59·5

On the other hand, the results of observations made on the performance of Mr. Griffin's open grate, with warming and ventilating appliances, in a private room at 27, Cadogan Square, showed a remarkable degree of uniformity. The difference of temperature at the four sides of the room, which was 25 feet long, 18 feet wide, and 13¾ feet high, seldom exceeded 2° Fahr.; nor did the temperatures at the ceiling exceed by more than 2° those observed at a level of 4½ feet above the floor. And it may be added that other experiments made on the Galton ventilating fireplace used in barracks, which was not brought into competition at the Smoke Abatement Exhibition, showed that when this grate was in full action, and the windows and other means of ventilation closed, thermometers in all parts of the room, and near the ceiling and floor, sheltered from the radiation of the fire, did not vary more than 1° Fahr.

The fact is that these two grates supply a large volume of air at a moderate temperature, delivered in a position to enable it to intermix under favourable circumstances with the currents of air in the room caused by the open fire; and this secures equalisation of temperature over the room.

These grates are essentially for burning Wallsend coal, but no doubt Mr. Griffin's grate might be advantageously used for burning anthracite. Mr. D. K. Clark made numerous experiments on various sorts of coal. He found that the steam coals evaporated a little more water per hour, and more water per round of fuel, in the ratio of 10·95 lb. to 10·05 lb., or nine per cent., than the anthracite. In order to supply the required quantity of steam, the anthracite were burned off more rapidly than the steam coals, or the excess of 377·5° Fahr. of temperature of escaping gases over 335·5° Fahr. This is due to the paucity of flame-borne heat from the combustion of anthracite, in contrast with the greater volumes of bright flame emitted in the combustion of the steam coals.

He, moreover, found that the Northumberland coal burned off more quickly, and evaporated water more rapidly, than the Nixon coal; but that the Nixon was the more efficient, as it evaporated more water per round of coal than the Northumberland, and, correspondingly, that the temperature at which the burnt gases of the Nixon coal passed away was the lower.

These inquiries are interesting in that they bear upon the question of what fuel

is most efficient in the several forms of domestic grates; and in connection with this we append the following table, which gives the average rise of temperature and radiation per pound of fuel consumed per hour, with air-heating appliances, and the same particulars without them, for each class of grates. The smoke-shades are added.

Class and Condition.	Average rise of temperature per lb. per hour.		Average radiation per lb. per hour.		Average smoke-shade for Wallsend coal.
	Wallsend.	Anthracite.	Wallsend.	Anthracite.	
1	2	3	4	5	6
	Deg. F.	Deg. F.	Deg. F.	Deg. F.	
Class 1. Air-heating . .	3·37	3·24	2·88	1·59	3·22
„ Non-air-heating .	2·45	2·90	4·21	4·99	2·78
Totals .	2·88	2·97	3·58	4·31	3·01
Class 2. Air-heating . .	2·81	—	3·93	—	4·11
„ Non-air-heating .	3·02	—	4·09	—	3·09
Totals .	2·99	—	4·07	—	3·23
Class 3. Non-air-heating .	3·81	—	3·61	—	2·82
Class 4. Air-heating . .	2·41	3·01	2·42	2·44	2·23
„ Non-air-heating .	3·37	1·98	3·50	2·98	2·88
Totals .	3·05	2·50	3·14	2·71	2·66
Class 5. Air-heating . .	3·45	3·77	4·00	3·51	2·29
„ Non-air-heating .	3·28	2·89	3·22	4·76	3·21
Totals .	3·38	3·27	3·70	4·22	2·73

The total averages of all classes show that Wallsend coal is used with greater economy without than with air-heating appliances; and that, on the contrary, anthracite is used with the greater economy with air-heating appliances. For anthracite, the relative economy of air-heating appliances is visible for every class of open grates in which it is used. For Wallsend coal, the several classes of open grates show results alternately in favour of heating appliances and against them. This is what might be expected, because the Wallsend coal produces a bright flame, whereas anthracite coal only affords a red glow. The bright flame radiates into heat rapidly, and warms the walls and furniture sufficiently rapidly to enable their surfaces to communicate warmth to the air of the room. The anthracite, on the other hand, radiates the heat more slowly, and therefore there will probably be less comfort with the anthracite than with Wallsend coal.

It may be concluded that the evidence is not decidedly for or against the use of air-heating appliances, in burning Wallsend coal, except in the case of the comparatively wasteful open grates of Class 1, with which such appliances are clearly conducive to economy.

The radiating-power, indicated in columns 4 and 5 of the table, is, as might be expected, materially greater in the absence of air-heating appliances than when they are present:—for anthracite in every class; for Wallsend coal in every class except Class 5, open grates, having a downward or a backward draught.

CHAPTER LIV.

CLOSE STOVES.

Brick Stoves—The German Stove, and its Modifications—Economy, and Disadvantages—Iron Stoves—Stoves or Furnaces for Heating Air—Various Recent or Improved Stoves.

THE next method of heating to which we will refer is by means of stoves. The term stove is applied to the apparatus which consumes the fuel in a close receptacle, as distinguished from an open fire, and which gives out the heat directly to warm the air. Stoves may be used to warm rooms, or else to warm air to be afterwards used in warming rooms.

A stove absorbs, utilises, and gives out sooner or later all the heat which the fuel develops, except that part of the heat which passes away with the smoke and products of combustion. The difference in the value of different stoves consists in the proportion of heat which can thus be utilised in the space the stove is designed to warm, which may be termed its calorific result. A stove entirely enclosed in the space it is designed to warm will give the best calorific results, because the whole heat given out must pass directly into the space to be warmed. But stoves are also applied to warm fresh air which is intended when warmed to be passed into some other room. In this case the air, after being warmed, will lose more or less of its heat in passing along the flues of transmission. If these flues are of great length, in a situation exposed to damp, and formed of materials which are good conductors of heat, much heat may be lost in transmission. It must, however, be remembered that flues entirely inside a house, even if they absorb the heat, must give out the heat again into the house somewhere. It is on this account that it is so much more advantageous to place chimneys in the inside walls of a house, so that the heat which the brickwork absorbs during the passage of the smoke passes into the house instead of into the open air, which is largely the case with chimneys in outside walls.

In a close stove, heated to a moderate temperature, the heat, as it passes from the fire, warms the surface of the materials which enclose and are in contact with the fire and with the heated gases, and transfers the heat through the materials to the outer surface in contact with the air; and the air is warmed by the agency of this outer surface. If heated to high temperatures it gives out radiant heat which passes through the air to warm the object on which the rays impinge.

Brick stoves and flues are worse conductors of heat than iron stoves or flues, but the surface of a brick stove, especially if glazed, parts with the heat which reaches it somewhat more rapidly than do the surfaces of an iron flue. But the whole of the heat generated does not reach the outer surface with the same rapidity. The slow conducting-power of the material, and the greater thickness, of a brick stove prevent alternations which may take place in the fire from being felt so much with brick stoves as with iron stoves or flues; and therefore the brick stove warms the air more equably without sudden variations; the air so warmed is free from objectionable effects; and where they can conveniently be applied, it is advisable to use brick stoves for warming air for ventilating purposes.

Of the various forms of brick stoves the most notable is the German stove. This stove is constructed on the plan of economising the heat. This economy is produced by the internal arrangement, which compels the heated gases from the fire to pass backwards and forwards through flues in the stove before they flow

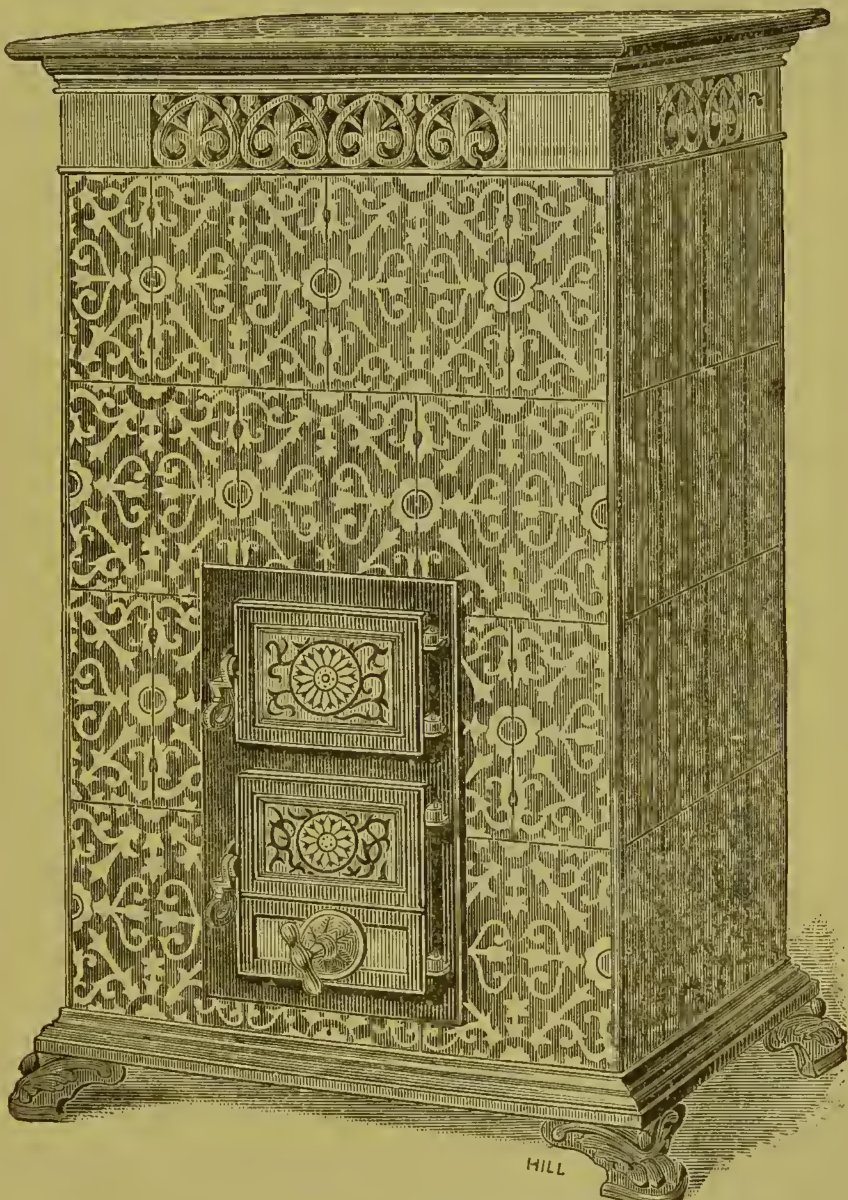


Fig. 221.—Doulton's German Stove.

away into the chimney; and thus the greater part of the heat is retained in the body of the stove. After the fire has been lighted in the stove and well burned up, the doors and dampers of the stove are closed so as to prevent any draught passing through the stove and carrying away the heat up the chimney; the fire is allowed to go out, and the heat thus passes out through the body of the stove into the room.

The German stove does not, however, act as a ventilating apparatus, because its principle is that the fire when once well burned up, shall be shut up, and thus obtain no air, or at all events very little, from the room in which it is placed. In

German rooms, therefore, the purity of the air is frequently left to depend on the spontaneous change of air which can take place through crevices of windows and doors, or through the walls.

This absence of ventilation is a main cause of the saving of fuel in German stoves. This saving of fuel must, however, be at the expense of health. Dr. Böhm (than whom no one has better studied ventilation) has adopted for some years the following system in the Rudolf Hospital at Vienna. He there warms fresh air by means of passages constructed in the fire-clay stoves placed within the ward, and

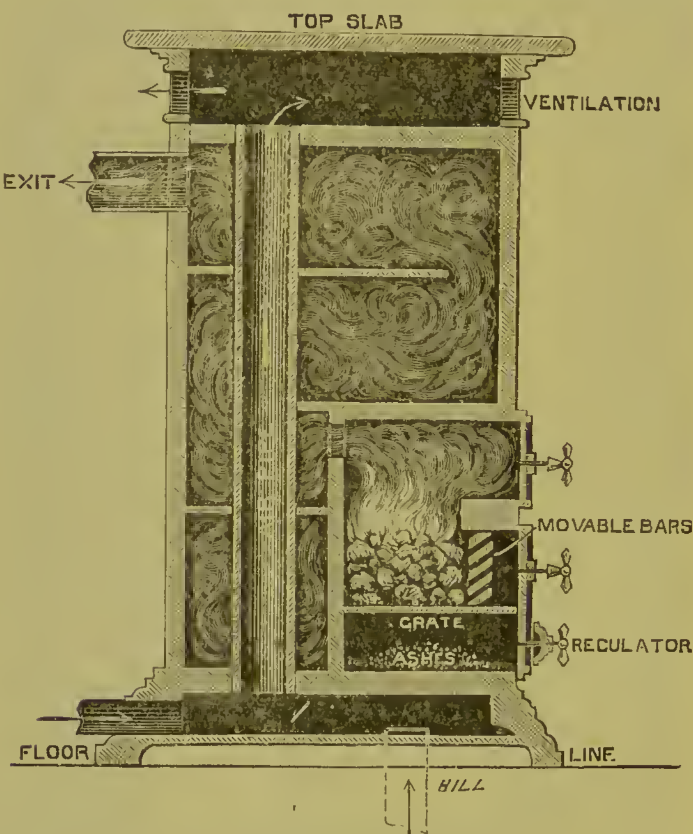


Fig. 222.

the fresh warmed air passes into the ward from the top of the stove. He provides flues of a large size, and proportioned to the size of the ward, from the level of the ward floor to above the roof, and the difference of temperature between the air in the ward and the outer air causes a sufficient current in these flues in cold weather to ventilate adequately the ward. By this means the fresh warmed air, instead of passing off to the upper part of the ward, and thence away by flues, is made to circulate towards the floor of the ward, thus bringing into action the principle by which the open fireplace is useful in ventilation. But this arrangement destroys one element of economy in the German stove, because the heat generated, instead of being left to pass slowly off into an unventilated room, is removed rapidly by the fresh air passed into the ward, and has, therefore, to be renewed at intervals, instead of, according to the usual custom, the stove being left shut up for twenty-four hours to give off its heat slowly. The larger the supply of warmed air, the larger must be the consumption of fuel; and if the heat is to be supplied economically, it must be through

a good conducting medium; but the material of the German stove is a bad conductor of heat. On this account the German stove is not universally applicable, but it is of great benefit and advantage in special cases.

Messrs. Doulton have recently made a form of stove, on the principle of the German stove, in various sizes, which would advantageously take the place of many of the forms of iron stoves, and which is very economical of fuel, but it is not smoke-preventing. The accompanying Fig. 221 shows one of Doulton's Lambeth Radiating Tile Stoves.

Messrs. Doulton have also adapted their form of German stove to warm fresh air admitted from the outer air, as shown in Fig. 222.

There are numerous other forms of stoves which are designed to warm fresh air, in which the fire is placed in a fire-clay receptacle, and the air is passed through flues cast in the fire-clay. These afford a very convenient and equable means of warming the air, but they do not possess the same elements of economy as the German stove.

Iron is a very useful material for stoves. Iron lends itself readily to convenient forms, and it is a very good conductor of heat. The consequence is that iron has been more largely used than any other material for stoves. There are, however, several serious objections to iron stoves, especially for small rooms; a long flue-pipe is unsightly, and on that account often inadmissible. Iron stoves heat rapidly, and easily become red-hot, therefore the effect produced is unequal both on the air and on persons in the vicinity of the stove. An iron stove cools down with rapidity when the fire is low. The flue-pipe gives out unequal degrees of heat in the different parts of its length. With an iron stove the temperature at eighteen inches from the stove has been found to exceed by 27° Fahr. that observed at six feet from it; and with a red-hot stove the difference in that short distance has been found to be in some cases as much as 45°.

Carbonic oxide has been found in air heated by iron stoves. This can only occur provided the stove be very highly heated; but a high temperature is a liability to which many iron stoves are subject. Iron, very highly heated, may take up the oxygen from the carbonic acid prevalent in the air of an unoccupied room, and thus reduce the carbonic acid to the condition of carbonic oxide. Moreover, the quantity of dust in a room, which almost always contains organic matter, may under these conditions of temperature somewhat influence the presence of carbonic oxide.

General Morin alleges that he found these effects to be nearly three times as great with cast-iron as with wrought-iron stoves. It has also been alleged that the carbonic oxide generated in the flue may permeate through the cast-iron of the stove if very highly heated, or if made of inferior porous metal, into the surrounding air. Carbonic oxide may also be produced by the oxygen of the air acting on the carbon in the cast-iron if heated to a red heat. The effect would be diminished by the presence of moisture in the air. Consequently, the use of vessels containing water on metal stoves has been recommended. The use of surfaces of iron heated to a red heat for warming air for ventilating purposes is objectionable. Hence, whenever iron stoves or cockles are used for heating air, care should be taken to prevent the iron from attaining a high temperature, and with this object all iron stoves should have a lining of fire-brick, so as to prevent the fire from coming in direct contact with the iron; such an arrangement prevents these inconveniences, and preserves greater regularity in the heating of the air.

Almost the whole heat which any fuel is capable of developing may be utilised in a stove by using a long flue-pipe, horizontal for the greater part of its length, to convey the products of combustion to the outer air. The heat given out by a stove-pipe varies with the temperature from end to end, being of course greatest at the end next the stove, where the loss of heat is very rapid; and the amount of heat given out per square foot will vary at each point as the distance from the stove increases; and thus, in dividing the pipe into lengths, each giving out an equal amount of heat, the length of the portion of pipe at the end farther from the stove would be considerable, whilst the length required to give out an equal amount of heat near the stove would be very short. But not only does the amount of heat given out vary greatly from end to end of the flue-pipe, but the proportions into which the heat divides itself between the walls and the air vary greatly with the temperature.

Thus, with a stove-pipe heated at the end nearest the stove to a dull red heat of 1230° Fahr., and of sufficient length to allow the heat to be diminished to 150° at the farther end, it would be found that at the stove end of the flue-pipe 92 per cent. of the total heat emitted by the pipe is given out by radiation to the walls, and only 8 per cent. to the air; but at the exit end, the heat is nearly equally divided, the walls receiving 55 per cent. and the air 45 per cent. Taking the whole length of such a pipe, the walls would receive 74 per cent. and the air 26 per cent. of the heat emitted. But with a flue-pipe heated to lower temperatures, the air might receive half the heat or even more.

At very high temperatures there will be practically little difference of effect between horizontal and vertical flue-pipes, because the heat given out is principally that due to radiation, which is independent of the form and position of the radiant.

An adequate proportion of flue-pipes to the form and size of the stove involves a large surface for the flue-pipe; and with a careful observance of proportion, as much as 94½ per cent. of the heat in the fuel has been utilised, only 5½ per cent. being carried away.

As already observed, the inconvenience which a plain iron stove presents in consequence of the injury to the air which results from overheating, may be partly overcome by placing the fire in a fire-clay box or lining to the stove, retaining the iron for an outside covering. This class of stove is more expensive than a plain iron stove, but its use has much extended in late years. But there is another method of correcting the evils of overheating of the iron in a stove; viz., by proportioning the surface which emits the heat generated by the stove to the size of the fire. This is the principle which was adopted in the old form of cockle which was formerly the usual apparatus for heating fresh air in ventilation (which has now been generally superseded by hot-water pipes). It is also to some extent the plan in what are termed the Gurney stoves. A large surface for the emission of heat is provided in this stove by means of flanges cast all round the stove; the heating-surface thus afforded is intended to carry off the heat from the fire with sufficient rapidity to prevent the iron ever being unduly hot. Of course this requires the stoves to be used judiciously.

Notwithstanding that the old cockle for heating air has been superseded, it presents many advantages in certain cases, especially where the air is required to be warmed rapidly and occasionally.

The following is an account of one of the best forms of cockle, or "air-warmer." This form was invented by the late Mr. Sylvester, and has been continued by Messrs. Rosser and Russell.

The air-warmer consists of an external case of cast-iron, square on plan (Figs. 223 and 224), the sides being inclined outwards, so as to present the appearance of an inverted frustrum of a pyramid, resting upon a square foundation-plate of cast-iron, which is in its turn supported on a hollow cast-iron trough (G) that forms the outlet for the smoke.

Within the outer case described is an inner box, the sides of which overhang somewhat more than the sides of the outer case, meeting the upper edge of the

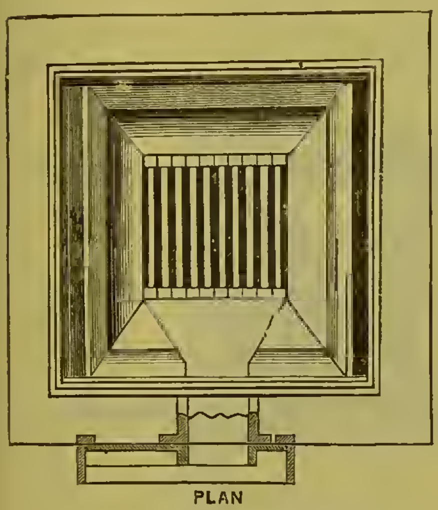


Fig. 223.

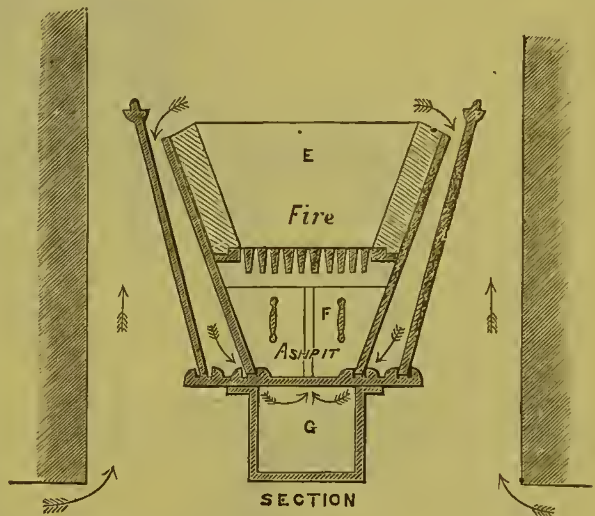


Fig. 224.

latter at back, and approaching within about 2 inches of the margin at the sides. On the fourth side, the outer case forms also the boundary of the inner box, and on this side, which forms the front of the apparatus, are the doors of the furnace and ash-pit.

The upper portion of the inner box contains the furnace (E), the sides of which are lined with fire-brick, and below the furnace-bars, in the lower part of the inner box, is the ash-pit (F), at the back of which are movable plates, which give access to the space between the two cases for the purpose of sweeping.

The whole is covered in by a cast-iron pyramidal top (Fig. 225), which has upon its external surface laminated ribs, cast on the pyramid, for the purpose of obtaining the desired extension of surface. The exterior of the lower case is also ribbed in a similar manner, but the ridges have less depth, and are sometimes arranged at an angle with the plate, for the purpose of breaking the film of air in contact with the metal.

Resting on the ribs of the pyramidal top are sheet-iron plates (D) which reach from the sides of the heating-chamber to the shoulder of the pyramid, which is truncated at its upper part.

The object of these plates is, 1st, to confine the ascending currents of air to the channels between the ribs; and, 2nd, to conserve the heat radiated from the pyramid, and return it to the air.

Doors, both to the fire and ash-pit, move on planed surfaces, and shut air-tight. The ash-pit door serves also as a supplementary damper, and is capable of the nicest regulation.

The operation of this apparatus is as follows :—

The fire which occupies the centre of the inner box, being made in a fire-brick lined chamber, is capable of very vivid combustion, with a proportionately powerful radiation. The rays of heat are received by the interior of the pyramid. The heat taken up by the inner surface of the pyramid is transmitted through the metal to the exterior, and by conduction to the extremities of the ribs. The sides of the

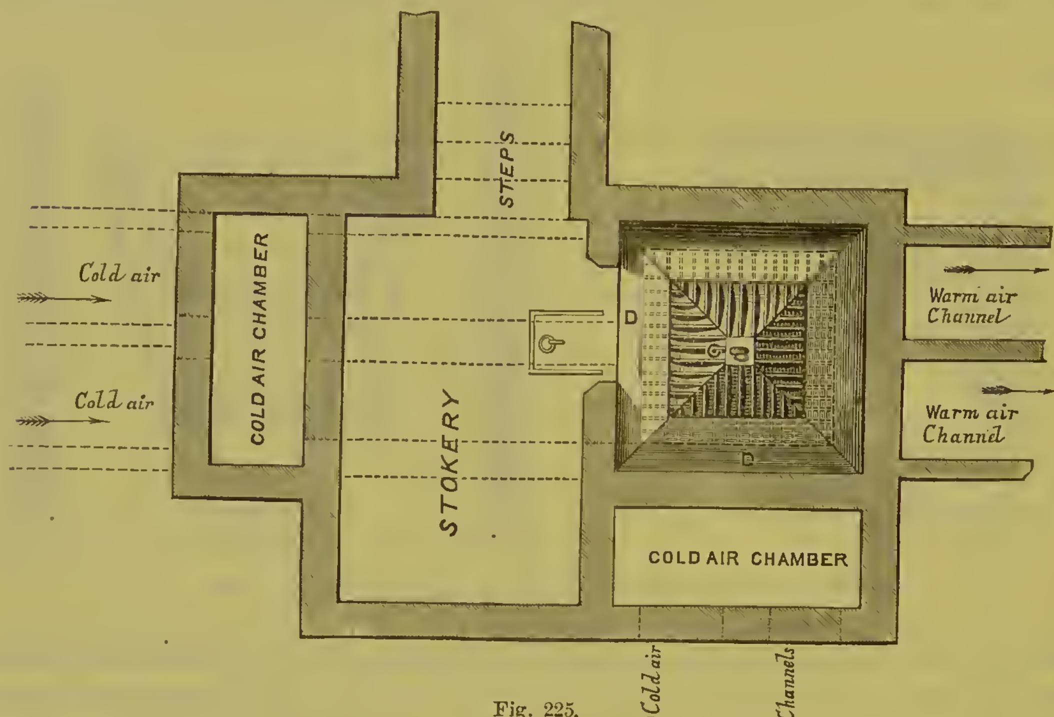


Fig. 225.

stove are heated by the smoke which, passing over the edges of the inner box, descends in the space between the two boxes and goes out through a hole in the foundation-plate behind the ash-pit, into the trough-flue, upon which the stove rests, and thence into the chimney. The heat-receiving surface of the outer case and bottom flue is 95 feet; and the total exterior heating-surface exposed to the contact of the air is 320 feet. The stove is set in a chamber of brickwork, to the lower part of which cold air is admitted by openings below the level of the bottom flue. The cold air first comes in contact with the exterior of the bottom flue, receiving its first portion of heat from the *coolest* of the smoke. This is one of the peculiar advantages of the descending arrangement where the flue is used for warming fresh air, which we have already alluded to.

The air, having received its first portion of heat from the bottom flue, ascends around the sides of the stove, the upward current being partly deflected and broken by the change in the direction of the ribs. Having reached the upper margin of the lower case, its farther movement in a vertical direction is arrested by the striking-plates, which reach from the enclosing walls of the chamber to the shoulder of the stove. The current, being thus deflected, is obliged to pass between the

deep ribs of the pyramidal top, the spaces between which form so many small channels in which the comparatively thin films of air are brought into contact with a proportionately large heating-surface. In these channels the air acquires a very high velocity, amounting to from six to ten feet per second, which not only assists it in extracting the heat from the ribs but is eminently serviceable in giving the

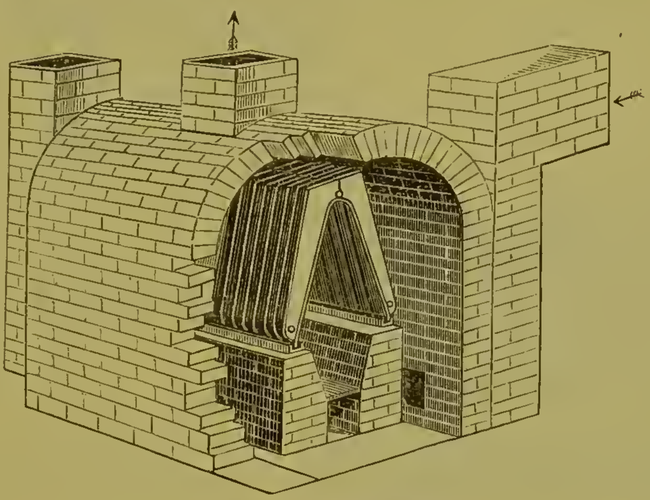


Fig. 226.—Gill Stove.

initial power necessary to the subsequent transmission of the warm air through extensive ranges of horizontal flues.

Some of the largest churches in England are warmed by this apparatus, but it will be found particularly applicable for small churches in rural districts, on account of its simplicity of construction and management.

Fig. 226 is a view of a Gill stove. The name of Gill stove was given by Mr. Sylvester to this stove from the fancied similarity in the arrangement of the plates which compose the stove to the gills of a fish. The apparatus is of very simple construction, consisting merely of a series of cast-iron plates bolted together, the inner edges of the plates being exposed to the fire, and their outer surfaces to the air.

Fig. 227 is an enlarged section of a portion of a plate, showing the way in which they are combined together. A stove may consist of almost any number of plates. These stoves are very simple and easily repaired, but of course they are subject to the disadvantage that if the fire is neglected the stove cools down rapidly; and it is probably mainly on this account that hot-water and steam pipes have gradually superseded them.

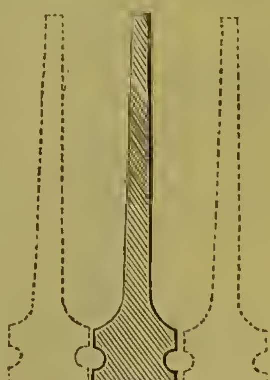


Fig. 227.

The newest forms of stoves must be assumed to be those exhibited in the winter of 1881-82 at the Smoke Abatement Exhibition, and we have therefore taken from the Report of the Smoke Abatement Committee the following tabular statement of some of the principal results of the tests of the close stoves burning bituminous coal which were successful in obtaining awards in the competition at that Exhibition.

Name of Exhibitor.	Description.	Fuel Consumed. Coal per hour.	Ash.	Temperatures. External.	Average at walls 6ft. high.	Average difference due to Radiation 5ft. high, 6ft. from fire.	Chimney. Average velocity of Draught.	Average Temperature.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Carbon as $Cx\ Hy + CO$.	To every 1,000 parts of Carbon as CO_2, there are of Hydrogen free and combined with Carbon in the gaseous state.	Smoke-Shade. Average.
	Bituminous Coal.	lb. oz.	lb. oz.	Deg. F.	Deg. F.	Deg. F.	Feet per min.	Deg. F.			No.
C. B. Gregory.	Smoke-burning Furnace, enclosed in a cubical casing of cast-iron, lined with fire-brick. The fresh fuel is charged into a steeply inclined hopper of fire-brick, and falls upon a horizontal grate. Air is admitted to the fuel at the lower part of the hopper, and through the grate; air is also admitted at the front. It passes along the sides in contact with and heated by the hopper, and is discharged at the throat of the furnace at the back, in two streams, from opposite sides, meeting and mingling with the combustible gases from the fire. Complete combustion is thus effected.	21 0	—	42·0	79·68	13·86	666·0	—	—	—	0·00
Rev. H. J. Newcombe	A tubular air-warmer, consisting of a group of horizontal pipes, connected with a close stove, from which the gases pass through the pipes. The soot is swept from the tubes into a reservoir. The air of the room or hall circulates around the pipes and becomes heated.	3 7	0 4	42·0	58·60	3·60	173·0	90·0	49	20	2·00
John Cornforth.	An oblong rectangular stove of cast-iron. The fire-bars are hollow, and are traversed by air which is heated on its way through, and is delivered upwards at the bridge, so as to meet and mingle with, and consume the combustible gases passing from the fire.	3 12	1 12	50·0	88·41	15·36	430·0	180·50	7	39	0·09
J. F. Farwig & Co.	"Calorigen" slow-combustion stove. Within a cast-iron cylindrical casing, a cylindrical fuel-chamber of fire-clay is placed eccentrically, filled with coal, which is lit from the bottom, to which the supply of air is regulated. A fresh-air chamber is placed beside the fuel-chamber, overlapping it sidewise, in which external air, admitted below, is warmed; the air being discharged at the upper part.	2 12½	2 9	43·0	62·20	6·18	—	207·0	114	31	1·16
J. Dunnachie.	An upright square stove of fire-brick in an open cast-iron casing. It is divided diagonally into two compartments by a partition, over which the gases pass and descend on the other side of the partition: they then pass off into the flue. Air for combustion is admitted behind the lower part of the partition, becoming heated, and passing through holes in the partition into the fireplace.	5 0½	4 9	40·0	53·50	12·20	560·0	312·0	34	94	2·48
R. W. Crosthwaite.	Armstead-Gregory Stove: a combination of Armstead's stove and Gregory's stove.	7 2½	1 1	51·0	70·15	17·10	455·0	196·25	16	30	0·46
E. H. Shorland.	Warm Air Ventilating Stove, for large buildings. G. L. Shorland's patent. A cubical stove, having a casing of cast-iron, made with gills externally, three-eighths of an inch deep. The fireplace is square, and is enclosed at the sides and the back by air-warming chambers. A few steel turnings are suspended in the fireplace, which, becoming red-hot, are expected to be useful in burning smoke. Fresh air is led into a shallow reception chamber at the base of the stove. Thence it passes upwards through the air-warming chambers, which are made with partitions by which the air is caused to ascend in a zigzag course. The air passes from the upper parts of these chambers into pipes, which rise from each side, and from the back, meet at the middle of the stove over the fire, and deliver the warmed air into a shallow receptacle on the top of the stove, whence it passes through numerous openings into the room. These openings are formed by short pieces of tube which are fixed to the bottom of a shallow tray containing water, and rise through the water. By this means, moisture is distributed with the air into the building. The products of combustion are led away through a descending flue at the back, under the floor. (Burns silkstone.)	5 1	0 10	—	—	—	52·0	300·0	—	—	1·05

Of these stoves, the most remarkable was that exhibited by Mr. C. B. Gregory, of Beverley, New Jersey, U.S. In the form shown, it was, perhaps, rather more a "furnace" than a stove, applicable to domestic purposes. It was enclosed in a cubical casing of cast-iron, lined with fire-brick. The fresh fuel is charged into a steeply-inclined hopper of fire-brick, and falls upon a horizontal grate. Air is admitted to the fuel at the lower part of the hopper, and through the grate. Air is also admitted at the front; it passes along the sides in contact with, and heated by, the hopper, and is discharged at the throat of the furnace in two streams from opposite sides, meeting and mingling with the half-burned gases from the fire. Complete combustion is thus effected. When tested with an hourly consumption of 21 lbs. of Wallsend coal, no visible smoke was produced, a result not attained by any other apparatus. Its heating-power, as will be seen by a reference to the tables, was very great. In fact, as already observed, all stoves give a much greater result for the fuel used than the best of open fireplaces; but this result is obtained at the cost of the other comparative disadvantages already mentioned, and which will be again dealt with farther on.

Mr. R. W. Crosthwaite exhibited an Armstead's stove with Gregory's improvement, which gave excellent results; as did Cornforth's "Little Wonder" stove, the bottom bars of which are hollow, air heated by passing through them being admitted to support combustion, so as to prevent the formation of smoke. In this particular the arrangement appeared very efficient.

Amongst other stoves exhibited which may be mentioned was Jobson's Slow Combustion Gill-stove. It consists of a number of open frame-like diaphragms laid side by side, and bolted together with front and back plates, forming a close stove with twenty exterior gills. It is divided into two unequal parts by a vertical partition, the larger of which is the fireplace, having a grid at the lower end and an ash-box. The draught is passed directly upwards for lighting up, and is next reversed, passing downwards through the grate, and upwards through the smaller compartment to the flue. The gases are met by a current of air issuing from the partition, which is hollow, to be consumed.

And also Doulton's Spiral Stove may be mentioned, consisting of several superposed rings forming chambers. The fireplace is formed in the lowest chamber, whence the gaseous products rise into and pass round each ring in succession; they pass off from the uppermost ring to the chimney. The rings are supported one on the other by perforated edges, through which air enters and becomes heated. The heated air passes into and flows up the central cylindrical shaft, whence it is discharged through a perforated covering. Air also is admitted into a compartment next the fireplace, and being there heated, joins the other currents of air and escapes at the top.

Messrs. Doulton also exhibited a Top-feeding Stove, in stoneware. This is a square upright stove, divided by a vertical partition, forming at one side a hopper for the charging of coal, which gradually falls to replace the fuel consumed. The gaseous products pass through an opening near the base of the partition into the other compartment, where they meet an additional supply of air; and from the upper part of this compartment the gases pass into the flue. It is designed thus to consume all the smoke. Fresh air is admitted into the lateral warming-spaces, from the upper parts of which it escapes into the room.

The following were the successful stoves for burning anthracite or coke:—

Name of Exhibitor.	Description.	Fuel Consumed.		Ash.		Temperatures.			Chimney.		Chemical Tests.		Smoke-Shade.
		Coal per hour.				External.	Average at walls 6ft. high.	Average difference due to Radiation 5ft. high, 6ft. from fire	Average velocity of Draught.	Average Temperature.	To every 1,000 parts of Carbon as CO_2 there are of Carbon as $Cx\,Hy + CO$.	To every 1,000 parts of Carbon as CO_2 there are of Hydrogen free and combined with Carbon in the gaseous state.	Average.
	Anthracite and Coke.	lb.	oz.	lb.	oz.	Deg. F.	Deg. F.	Deg. F.	Feet per min.	Deg. F.			No.
Musgrave and Co.	Slow-combustion Stove. An upright cylinder of cast-iron, lined and floored with fire-clay, having an ash-door at the bottom and a feeding-door at the top. The gases rise to the top, and pass over the back into a descending flue, whence the current turns under a partition into an ascending flue, whence, by a nozzle at the upper part, it passes into the chimney. Fresh air is admitted at the lower part into a casing enveloping the cylinder and the flues. It is warmed as it ascends in contact with their surfaces, and escapes into the room at the upper part.	2	$3\frac{1}{2}$	5	4	43·0	77·86 65·01	9·85 5·00	117·0 —	400·0 160·0	61 —	37 —	0·00 —
Harry Hunt.	"Economy" Base-burner Hall Stove, for smokeless fuels. The body is a cylinder of cast-iron, on a cast-iron base to provide the base flues. The fuel is burned in a cylindrical fire-pot of fire-clay, like that of the "Economy" Portable Stove, having a tilting grid at the bottom. The fuel is filled into an upright hopper above the fire, whence it is supplied by gravitation as the fire burns away. The gaseous products pass over the top of the fire-pot, and descend at each side into the base of the stove, beneath the fire-chamber, within which they circulate. Thence they pass off by a flue-pipe to the chimney. The charging-door is formed with panes of talc.	2	$8\frac{3}{4}$	0	5	42·0	51·44	3·31	212·92	165·83	—	—	—
Harry Hunt.	"Crown Jewel" Base-burner Hall Stove, for burning anthracite and other smokeless fuels. The fuel is burned in a hemispherical fire-basket of cast-iron in three pieces; the body and the grid-saucer, with a sliding plate at the bottom. The body is grilled all round at the lower part for the admission of air, in addition to the air admitted through the grid. The plate may be shaken, or it may be withdrawn, to let fall the ash, or the whole of the fire, into the ash-pan. The draught passes over the edge of the fire-basket, and descends to the base, where it circulates below the ash-pan prior to passing off to the chimney by a back flue.	2	$6\frac{1}{2}$	0	12	36·0	51·90	6·58	177·89	181·43	114	66	0·0
Franz Lönholdt.	Anthracite Stove, base-burning. It is an upright stove of cast-iron, having panes of talc to show the fire. The fire is contained in a circular basket, into which the fuel is supplied from an upright cylinder or hopper above the basket. It has a bottom grid, which is movable for shaking out ash and cinders, without causing dust, as the ash falls into a pan enclosed beneath the grate. The grate-basket is isolated, and does not touch the inner casing in which it is enclosed. Air from the room, as well as fresh external air, circulates through upright tubes at the sides of the grate, where it is heated and whence it passes in upward streams into the room. Foul air from the room is passed through a ventilator into the smoke-flue before it enters the chimney. The products of combustion are drawn downwards, and they circulate in the base of the stove before they pass to the chimney. The supply of air for combustion can be regulated or shut off. By this means, with the admission of air into the flue, the fire in the stove can be regulated to burn several days and nights continuously, with one supply of fuel. If charged with fuel at intervals of from twenty-four to forty-eight hours, the stove burns continuously throughout the winter.	1	$4\frac{3}{4}$	0	5	40·0	53·48	4·81	181·25	83·25	132	109	1·50

Name of Exhibitor.	Description.	Fuel Consumed. Coal per hour.		Ash.		Temperatures. External.	Average at walls 6ft. high.	Average difference due to Radiation 5ft. high, 6ft. from fire	Chimney. Average velocity of Draught.	Average Temperature.	Chemical Tests. To every 1,000 parts of Carbon as CO_2 there are of Carbon as C_xH_y + CO.	To every 1,000 parts of Carbon as CO_2 there are of Hydrogen free and combined with Carbon in the gaseous state.	Smoke-Shade. Average.
	Anthracite and Coke (*continued*).	lb.	oz.	lb.	oz.	Deg. F.	Deg. F.	Deg. F.	Feet per min.	Deg. F.			No.
H. J. Piron.	Ventilating Stove, burning anthracite. This is an upright cast-iron cylinder, enclosing an inner cylinder, of which the lower part is occupied by the fireplace, and the upper part is narrowed to a swan-neck form conducting the gaseous products to the flue-pipe. The fireplace is of iron, with a grid at the bottom. The air required for burning the fuel is drawn from the apartment; and the same air is allowed to pass upwards outside the fire-pot, to meet and mingle with the gaseous products, and to pass off with them. The interspace between the outer and the inner cylinder is occupied by fresh air admitted at the lower part, which is heated as it ascends, and passes into the room at the upper part of the outer cylinder. A pan of water is placed beneath the fire-pot, and water is lodged on the top of the stove for evaporation into the room. The casing is lined with a non-conducting substance.	6	10	2	4	48·0	62·64	7·64	331·0	248·0	35	53	0·0
J. Wadsworth.	The "Pioneer," a warming, ventilating, and cooking apparatus. A close stove, burning coke. The stove is cubical, of charcoal iron sheets, 36in. high, 20in. wide, 16in. deep. The fireplace, which is at the bottom, is 7in. by 6in., and 7in. deep, grated in front, with a hob-plate at the top, having a 6in. opening, with a hinged cover. The fireplace, indented into the casing, and flush with it, is enclosed and over-arched by plating, so as to leave a space above the hob for cooking. It is enclosed in front by a lean-to, paved with talc, to let the fire be seen. A sliding damper is fitted at each side of the fireplace, under the hob, to regulate the draught which passes off from the fireplace into the interior of the casing, where air is heated. The air to be heated comes from the external atmosphere through a pipe, and is delivered into a shallow chamber at the base, whence it passes upwards through five flat conduits, 30in. high, of which three are 5in. by 1in., and two are 3in. by 1in. Air from the room, near the floor, is also admitted at the base of the stove, to pass up through four conduits, 5in. by 1in. in section. Through the nine conduits here noticed the air passes upwards within the casing, enveloped by the hot gases from the fire. The air becomes heated as it ascends, and is distributed warm into the room through numerous apertures in a shallow chamber at the top, in which the heated currents of air are collected. Foul air is collected from the upper part of the room through a ventilator, and is conducted by a pipe in the chimney, where it becomes warm as it descends, and is delivered below and above the fire, to supply air for combustion. The products of combustion pass away through the back of the stove, at the level of half the height of the stove, into the flue to the chimney. Stray gases and fumes from the hob-plate are conducted through the crown of the arch enclosure into the flue-pipe. Cooking can be effectually conducted on the hob; and, by enclosing the space over the hob, small joints can be roasted.	2	15½	0	12	51·7	67·4	5·1	—	—	—	—	0·80

Among these stoves for burning smokeless fuel there were two which deserve special mention, viz., that of Franz Lönholdt, and the "Crown Jewel" stove of Harry Hunt. In these stoves a somewhat novel feature, the "base-burning"

arrangement, is introduced, which appears to give satisfactory results in improving the efficiency of the fuel. The former is also provided with a good automatic feeding arrangement, and the supply of the fuel can be so regulated that combustion is maintained with a very small expenditure, and the fire will burn for twenty-four hours or longer without attention.

Amongst the varieties of stoves are some which have been introduced and extended in late years, which are unprovided with any means for removing the products of combustion. From time immemorial use has been made in the south of Europe, in the winter, of "*braseros*," a metal dish or box containing lighted charcoal, employed to warm the room, or else employed as a foot-warmer. In large rooms with loosely-fitting doors and windows, such as are found in Spain, Italy, and Portugal, the fumes from the charcoal may have been comparatively innocuous. In more modern houses, with small rooms and with closely-fitting doors and windows, such an apparatus for heating the rooms becomes a serious source of danger, from the fumes of carbonic acid and carbonic oxide which they develop. Examples of death from the use of this method of warming rooms are numerous on the continent of Europe; and charcoal burnt in a dish used to be a favourite mode of suicide in Paris, until the theory was enunciated that death by charcoal fumes was very painful.

Similarly injurious are the stoves without chimneys, adapted to burn gas, mineral oil, paraffin, or other combustible, of which yearly new examples are introduced.

In cases where some small portable apparatus for the temporary warming of a room is wanted, it would be easy to avail oneself of the method adopted by the London and North-Western and some other railway companies for their foot-warmers. These are filled with crystals of acetate of soda, which melts at a temperature a little over 200°, and in the process of again crystallising it throws out the heat, and continues to do so in the case of the foot-warmers for twenty hours.

CHAPTER LV.

CHIMNEYS AND HEATING-POWER.

Temperature and Volume of Gases in Chimneys—Loss of Heat—Observations on Chimneys.

The temperature in the chimneys tested by Mr. D. K. Clark at the Smoke Abatement Exhibition averaged, for the whole of the open fireplaces exhibited, 197° Fahr. The temperature in the chimneys submitted to special tests averaged 222° Fahr. It was in some cases as high as 350°, and in others as low as 110°. It is evident that the efficiency of the chimney, as an engine of ventilation, depends upon the temperature.

The velocity of the draught in the chimney, in conjunction with the temperature of the ascending air-current, supplies a means of measuring the quantity of gaseous products and air in mixture, together with the quantity of heat which passes up the chimney.

In the experiments made for the Smoke Abatement Exhibition, the chimneys were circular, and averaged 8¾ inches in diameter. As already stated, the temperatures of the ascending currents from the open grates (Classes 1 to 5) were about 197° Fahr., and the volume of gases passed up the chimney per hour averaged 7,500 cubic feet. The following table shows the volume of the draught in the chimney, per lb. of coal, for the several classes of grates :—

Class.	Volume of gases passed up chimney per lb. of coal.	Average rise of temperature in the room per lb. of coal.
	Cubic feet.	Deg. Fahr.
1	1,904	2·88
2	2,266	3·18
3	2,440	3·81
4	2,134	3·05
5	1,875	3·38
Average.	2,099	3·26

From this it appears that, in round numbers, the open grates passed up 2,100 cubic feet per pound of fuel consumed.

The grates (Class 3, underfed) which passed up the maximum quantity of gaseous mixture per pound of coal consumed—2,440 cubic feet—are precisely those which develop the maximum efficiency, 3·81 degrees rise of temperature per pound of coal, notwithstanding that the combustion is not generally of the most nearly complete character.

And it is still more notable that the open grates of Class 5, having a downward or a backward direct draught, and which afford the minimum quantity of mixed current up the chimney—1,875 cubic feet per pound of fuel—rank next in efficiency to those (Class 3) which send up the maximum current. They raise the temperature 3·38 degrees per pound of fuel burnt per hour.

Thus the two classes which direct the draught through the incandescent fuel—

upwards in Class 3, and downwards in Class 5—exhibit the maximum efficiency for open grates; although the class with the upward draught causes the largest, and the class with the downward draught causes the smallest, volume of gases to pass away up the chimney.

Mr. D. K. Clark's experiments enabled him to form a very fair idea of the distribution of the heat generated by the open fire, and the following are the general conclusions upon this subject at which he arrived in his report.

Supposing that the fuel is perfectly burned, it may, for the present purpose, be assumed that 150 cubic feet of air at 62° is consumed in burning one pound of fuel, and that the gaseous products of combustion evolved occupy equal volumes at equal temperatures. But inasmuch as an average of 2,100 cubic feet of upward current passes off, for each pound of fuel consumed in open grates, it follows that the direct chemical products of combustion are diluted to the extent of 14 volumes; that is, that the direct chemical products are mixed with thirteen times their volume of air.

This current consists, for by far the greater part, of atmospheric air, and therefore its specific heat may be taken as that of air, namely, 0·238. Its specific gravity may also be taken as equal to that of air. 1 lb. of air at 62° Fahr. has a volume of 13 cubic feet, therefore the weight of 2,100 cubic feet passed off for 1 lb. of coal is $(2{,}100 \div 13 =)$ 161 lbs., and the quantity of heat carried off per pound of coal is $(161 \times 0{\cdot}238 =)$ 38·3 units for 1° rise of temperature. The average temperature of the escaping current was 197°; and, deducting the external temperature, which averaged 40°, the rise of temperature was $(197 - 40 =)$ 157 degrees. The total quantity of heat of combustion carried off was, on this basis (38·3 units $\times$ 157 =), 6,013 units for each pound of coal. The heat of combustion of coal of average composition, which may for the present be adopted, is equal to 14,000 units, and it follows that the wasted heat carried up the chimney is $(6{,}013 \times 100 \div 14{,}000 =)$ 43 per cent. of the total heat of combustion.

It is here assumed that the fuel is completely burned. But usually, to a great extent, the combustion is incomplete, and therefore the percentage proportion of heat sent up the chimney may be greater than this.

The next point to consider is how the heat of combustion is distributed. Assuming 43 per cent. of the total heat of combustion of coal from open grates passes up the chimney, and 24 per cent. from close stoves, the remaining 57 per cent. and 76 per cent. respectively are dispersed by conduction through the back and sides of the grate, by air-convection at the heated surfaces of the grate, by radiation, and by a remainder due to incompleteness of combustion. Of these, the heat that is radiated from the open fire, or the close stove, constitutes the largest proportion. According to the results of M. Péclet's experiments, one-fourth of the total heat combustion of wood was radiated; and one-half that of charcoal; flaming fuel in the first case, flameless in the second case. For the case of coal, it may be accepted that the proportion of heat radiated from the fuel varies between these limits.

To form, incidentally, an estimate of the proportion of heat absorbed in raising the temperature of the air in the room, let it be assumed that all the air which goes up the chimney is previously heated to the temperature of the room:—that is, taking averages, that 2,100 cubic feet at 62°, per pound of coal, for open grates, are

raised from the temperature of the external atmosphere to the average temperature in the room. According to the results previously mentioned, an elevation of temperature would have taken place from 40° to 57°, or 17°. The heat required to raise 2,100 cubic feet (at 62°), or 161 lbs., of air, through 17° would be (38·3 units × 17° =) 651 units. The quantity is 4·65 per cent. of the whole heat of combustion of one pound of coal. These would be the percentages of the total heat utilised in raising the temperature of the air in the room, even supposing the whole of the air that enters and leaves the room to be continuously replaced by fresh air. It is not, therefore, in simply warming the air in the room that the greatest consumption of heat takes place.

The enclosing walls, floor, and roof of the rooms are the principal absorbents of heat. It may be assumed that they are, in the course of the trial, raised in temperature to nearly, if not equal to, the maximum observed temperature of the air close to them.

It may be generally assumed from the experiments, that—

With open grates the heat carried off up the chimney was	43 per cent.
" " radiated and conducted heat, absorbed by walls .	42 "
" " lost by radiation and conduction externally and by imperfect combustion	15 "
	100 "

The experiments of the Smoke Abatement Committee afford a comparison between the heating-power of open fires and close stoves.

The general conclusions drawn from these experiments were that stoves are more effective than any class of open grates, for prevention of smoke. In the stoves, the supply of air for combustion is strictly regulated, and is forcibly mixed with the hot gases. The following table shows the most remarkable results of the performance from both methods, placed respectively in the order of efficiency :—

Class.	Exhibitor and Open Grate.	Wallsend, Anthracite or Coke.	Rise of Temperature per lb. of Fuel per hour.	Radiation per lb. of Fuel per hour.	Smoke-shade State 0 to 10.
No.			Deg. F.	Deg. F.	
4	H. E. Hoole. Reflector	W.	6·33	5·06	2·55
1	T. Potter and Son. Thermhydric... ...	W.	5·16	5·35	3·50
5	T. E. Parker. Vencedor	W.	5·06	2·79	2·28
5	M. Feetham and Co. Hurst Grate ...	A.	5·03	5·02	—
3	W. S. Melville. Shovel Underfeed ...	W.	4·93	3·50	4·14
3	E. R. Hollands. Underfeed	W.	4·90	3·62	2·52
1	Barnard and Co. Anthracite Grate ...	A.	4·90	—	—
3	E. H. Shorland. Undershovel	W.	4·71	4·68	3·00
5	Steel and Garland. Kensington	W.	4·58	3·60	3·66
5	The Coalbrookdale Company. Kyrle ...	A.	4·53	7·78	—
5	T. Feetham and Co. Hurst Grate... ...	W.	4·22 4·12	4·53 7·01	— 1·41
2	Barnard and Co. Glow Fire	W.	4·00 3·00	5·04 6·44	2·36 3·77
2	J. B. Petter. Nautilus	W.	4·12	3·38	2·81
2	Doulton and Co. Tile Grate	W.	3·78	2·59	1·33
5	J. T. Reeve. Filter Chamber Register Grate	W.	3·16	3·44	0·91
3	Brown and Green. Underfeed	W.	2·85	3·72	2·12

Class.	Exhibitor and Grate.	Wallsend, Anthracite or Coke.	Rise of Temperature per lb. of Fuel per hour.	Radiation per lb. of Fuel per hour.	Smoke-shade State 0 to 10.
No.	Close Stoves.		Deg. F.	Deg. F.	
	F. Lönholdt	A.	11·51	2·44	—
	W. Stobbs	A.	11·33	3·67	—
	H. Hunt. Economy Portable	A.	8·11	2·78	—
	Yates, Haywood and Co. Miser	W.	6·80	2·41	4·48
	H. Hunt. Crown Jewel	A.	6·66	2·00	—
	J. Cornforth. Little Wonder	W.	6·00	2·98	0·69
	H. J. Newcome	W.	4·80	2·02	2·00
	R. W. Crosthwaite. Gregory	W.	3·76	1·64	0·46
	Slow Combustion Tests for Long Periods.				
	Musgrave and Co.	C.	4·17	9·85	—
	B. J. Klivgenberg	W.	5·09	2·00	Not Observed
	C. Portway and Sons	C.	7·30	12·91	—
	F. Lönholdt	A.	13·41	11·18	—

The rise of temperature from stoves was about one-third better than the average of the open fires, and one-sixth better than the best. But the radiation was smaller with close stoves than with open fires.

The average smoke-shade in the close stoves, reckoned as before from 0 to 10, was 2·11, this being lower than the best of any class of open fires.

The stoves burning anthracite were more effective than those burning bituminous coal. The following table compares the close stoves with the average of classes 1, 4, and 5, open grates :—

		Anthracite. Deg. Fahr.		Wallsend. Deg. Fahr.	
		Close Stoves.	Open Grates.	Close Stoves.	Open Grates.
Close stoves	Rise of temperature per lb. of fuel . .	5·61	2·91	4·48	3·00
	Radiation per lb. of fuel	2·37	3·19	1·79	3·47

From this it is clear that with the close stoves the rise of temperature per lb. of fuel was much greater than the open grates, but that the radiation was remarkably low.

It was to be expected that there would be a greater radiation from open grates than from stoves, because the radiation from the front of the fire is unobstructed in the grates, whilst the radiation from the stoves is transmitted through the sides; but this radiation in the stoves was from all sides when the stove stood clear of the walls.

As regards the variation of temperature at different levels, the close stoves did not equalise the temperature in the room so well as the open grates, as may be seen from the following table :—

Class.	Air-heating and Ventilating Grates and Stoves. Temperatures at the following Levels above the Floor. Deg. Fahr.			Non-air-heating Grates and Stoves. Temperatures at the following Levels above the Floor. Deg. Fahr.		
	6 inches.	6 feet.	14 feet.	6 inches.	6 feet.	14 feet.
Averages of open grates, classes 1 to 5 . .	52·6	57·0	59·6	53·0	56·9	59·5
Close stoves . . .	50·9	57·2	62·4	63·0	68·8	71·0

The following is the average rise of temperature per lb. of fuel and radiation with stoves with, as compared to those without, air-heating appliances :—

	Average Rise of Temperature per lb. of Fuel per Hour.		Average Radiation per lb. of Fuel per Hour.		Average Smoke-shade for Wallsend Coal.
	Wallsend.	Anthracite.	Wallsend.	Anthracite.	
	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.
Air-heating . . .	3·79	7·79	1·78	2·32	1·58
Non-air-heating . .	4·23	4·64	1·64	2·39	2·25
Total . . .	4·14	5·61	1.66	2·37	2.11

The air-heating appliances do not appear to be economical with Wallsend coal, but with anthracite they appear to effect great economy. The velocity of draught in the chimney with close stoves averages 275 feet per minute, and the temperature in the chimney 200° Fahr.; and whilst, in round numbers, the open grates passed up, on the average, 2,100 cubic feet per pound of fuel consumed, the close stoves passed up only 1,160 cubic feet, or about half the quantity from open grates, which shows how much more ventilation is obtained by open grates than by close stoves. This was with the small chimneys used in the testing-rooms, which had an area of somewhere about 60 square inches. The area of a flue for an open fire in ordinary use is about 156 square inches; whereas the area of a stove-flue, as used in rooms and halls, rarely exceeds that of the flue in the testing-room; and consequently the difference in actual life in the amount of ventilation which would be afforded by an open fire over a close stove would be much greater than that shown by the experiments.

With close stoves the gaseous products in the chimney amount to about 12½ per cent., and the atmospheric air to 87½ per cent., or about 8 times the gaseous products; and it may be assumed that about 24 per cent. of the total heat generated by the fuel is carried up through the chimney—assuming that the fuel is completely burned, otherwise the proportion must be greater.

It further appeared from the experiments, that the heat from the combustion of the fuel was distributed as follows:—Heat carried up chimney, 24 per cent.; heat radiated and conducted by walls, 54 per cent.; heat lost by radiation and conduction externally, and heat lost by imperfections of combustion, 22 per cent. Thus a greater proportion of the heat generated is conveyed to the room and walls with close stoves than with open fires.

These are a few practical observations on chimneys which are worth noting.

A chimney to which less air is supplied than the fire requires, as may happen in a room with tight-fitting doors and windows, and without other apertures for the admission of air, often has two currents, as in Fig. 228, one upwards from the fire and another from the top downwards; these two currents meeting just above the fire, part of the smoke is driven into the room.

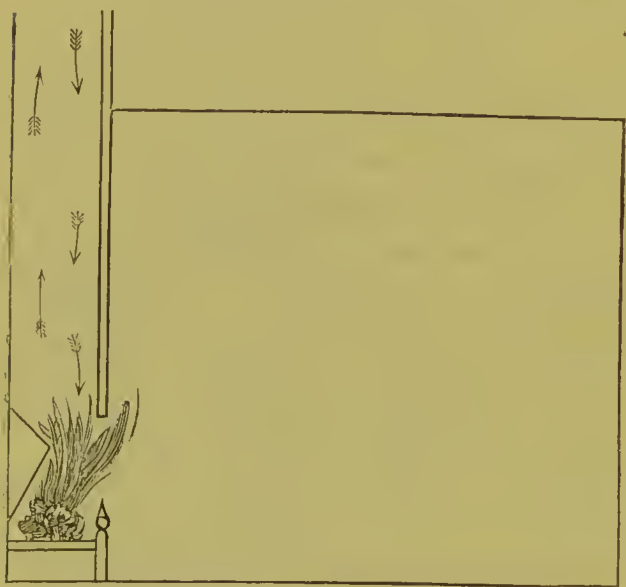


Fig. 228.

If the chimney be divided by a partition into two flues, one of which opens into the room at the side of the chimney, and the other directly over the fire, a descending current will be established in one and an ascending current in the other, which cannot interfere, and the smoking will cease.

When the chimney-breast is too high and the chimney large, the portion of air passing up the chimney is drawn from a large space, and the current being proportionally feeble, the flame which is usually drawn backward is left to rise vertically, and may escape into the room. The air which enters the chimney does not approach the fuel, and is consequently less heated, and the current is diminished.

If the chimney is brought down low, all the air passes near the fire, and the velocity of the smoke is increased.

When two chimneys are in the same room or communicate with each other through an open door, one will often overpower the other. To prevent this, a sufficient supply of air must be provided for each, without drawing upon the other.

If a chimney be colder than the air of the room with which it communicates, a current may be established downwards, and we may have not only the smell of soot but the smoke of a neighbouring flue, in the room. In the "Annales d'Hygiène' it is recorded that two individuals were found dead in their beds, in a room in which no charcoal had been burnt, and which had an open chimney without any fire in it. After careful investigation it was ascertained that a slow charcoal or coke fire had been kept in the next room, from which the fumes were carried up in a flue adjoining that of the room where the deaths occurred; and, partly by its overpowering influence, and partly by the coldness of the flue, the carbonic acid and carbonic oxide had descended into the room in sufficient quantity to destroy life.

If a chimney be narrowed at its lower extremity, the velocity of smoke through the opening will be greatly increased, but the total amount of air escaping will be diminished. If the narrow part be at the top of the chimney, the heated air will move more rapidly as it escapes into the atmosphere, often with a velocity which prevents its being blown down by the wind; but if the contraction is carried beyond a certain limit, it is followed by a diminution in the draught of the chimney which defeats the object. The chimney-top should never be less in area than one-half or one-third the diameter of the chimney.

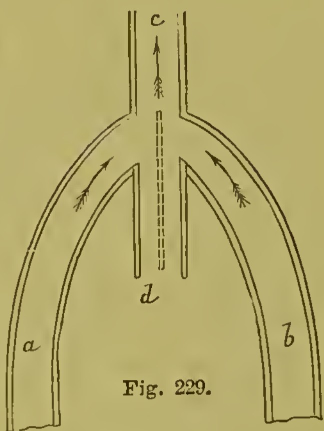


Fig. 229.

Every alteration in the area of a chimney to some extent diminishes the total amount of air escaping, and diminishes the power of the chimney as an engine of ventilation; therefore, alterations in area should be avoided as much as possible.

There are other points connected with the connection of chimney-flues which deserve notice, and which follow from previous remarks which we have made.

If two currents of smoke in the two flues, *a* and *b* (Fig. 229), having different velocities, enter another flue, *c*, at right angles, the one having the greater velocity will diminish that of the less, according to its excess. If the velocities be precisely similar, no change of velocity will take place in either; they will both be directed upward. The best mode of obviating the ill effects of such counter-currents is represented in Fig. 229, in which the dotted line, *d*, represents a division placed perpendicularly between the two currents, giving them both the same direction before they join.

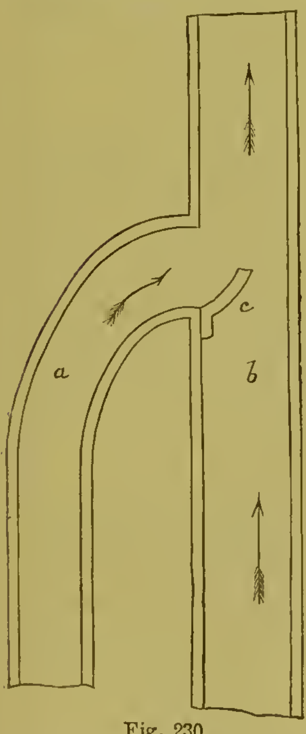


Fig. 230.

It has been observed that when a current of smoke from a flue enters a vertical chimney horizontally, it not only materially checks the current in the latter, but if the former is very rapid, it may even destroy that in the vertical chimney as effectually as a valve.

In such cases, the inconvenience of these opposing currents may be obviated by placing a plate of iron in the upright flue, as at *c* (Fig. 230), which shall give the smoke in the channel, *a*, a movement in the same direction as that in the channel *b*; this plate must be laid in such a manner as not to form a ledge for the accumulation of soot. In all cases of one flue entering another flue, the flues should be so arranged that the smoke shall assume a direction approaching that of the axis of the chimney into which they enter.

Where a flue is horizontal for a portion of its length, the connections with the vertical flue require great care; they should be carefully rounded so as to lead the gases in as favourable a manner as possible into the vertical portion; as a general rule it is prudent to make the vertical flue at least twice as long as the horizontal flue.

CHAPTER LVI.

GAS-HEATING APPLIANCES.

Advantages of Gas as Fuel—Gas and Coke Fires—Asbestos Fires—Various Forms of Gas-heating Stoves.

THERE has been much progress made of late years in the use of gas. This fuel is clean, smokeless, and with it a fire can be produced in full action at the moment at which it is wanted, and it can be put out as soon as the special purpose for which it has been wanted has been fulfilled. It is this advantage that makes gas economical in cooking, if applied under the direction of a careful housekeeper. But if the fire is allowed to go on burning after the immediate want is satisfied, then the economy of gas fuel soon disappears, But on the other hand the cleanliness and absence of dust with gas fires is so marked, that the use of gas would save an appreciable sum in servants' wages. In speaking of the question of economy, the Jurors of the Smoke Abatement Exhibition observed that the various apparatus which they submitted to trials showed a wide range of consumption, some apparatus requiring for the same description of work fully three times as much gas as others. They said that "The general tendency amongst manufacturers is evidently towards the study and application of economical principles; in which some have been already conspicuously successful, while still leaving room for further improvement. The fact that a 12 lb. joint can be cooked in London at a cost of very little more than a penny for gas, with a prospect that this may be farther reduced, ought to prevail with many a householder to try gas cooking, if only as an auxiliary to his present appliances."

Without doubt there is a great future before gas as a heating agent. If it were possible to adopt it universally in houses, the smoke nuisance would almost vanish. Therefore too much publicity cannot be given to the various uses to which it can be applied. For so simple a purpose as ironing, the laundress may be materially assisted by such an arrangement as was exhibited at the Smoke Abatement Exhibition, for keeping irons continually hot while in use by means of a gas jet. For the rapid heating of water for the supply of baths and other domestic purposes, gas was shown to lend itself with great facility; the action of the heaters consisting of the application of the gas to a stream of water on its flow from the pipe or cistern to the point of use, the temperature being raised in proportion to the quantity of gas used and the volume of water delivered.

Heating-stoves were represented by almost every conceivable form, from the suspended fire-basket to the elaborate and scientifically-constructed ventilating-stove. A ventilating-stove, when properly constructed and put in action, may be made to secure a constant ingress of warmed fresh air, and thus any desired temperature may be maintained in a room, without sensible variation for almost any length of time, and without the trouble of attendance and regulation. At the same time the products of combustion are carefully got rid of—a point of great importance, and upon which it is impossible to lay too much stress; indeed, the gas stove is only admissible when provided with a means for the escape of the products of combustion; especially as this condition may in all cases be satisfactorily fulfilled without

wasting much heat. It is also preferable that gas stoves should be adapted to supply fresh warmed air.

The tests which were made with the various heating-stoves exhibited show that any room of moderate dimensions may be effectually warmed by one or other of them with a consumption of gas not exceeding from 10 to 15 feet per hour. The following table shows the best results obtained at the Smoke Abatement Exhibition by Mr. D. K. Clark with gas stoves. The tests were made in the rooms already mentioned, the sizes of which have been given.

Name of Exhibitor.	Names of Apparatus.	Time under Trial.	Quantity of Gas consumed.	Temperature.						Temperature of Warmed Air delivered into the Room.
				External Average.	At walls 6ft. high.			Difference due to radiation 6ft. from fire, 5ft. high.		
					At commencement.	Total Average.	Average last hour.	Total Average.	Average last hour.	
		h.m.	cub. ft.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
J. C. Stark & Co.	Cox's Ventilating Gas Stove . .	4 0	57	36	50	55·45	57·67	0·66	2·33	290
Sanitary Association.	Dr. Bond's "Euthermic" Ventilating Gas Stove, Pattern B.	4 20	48	36	52·25	54·60	56·0	0·40	—	180
Ditto.	Ditto, Ditto, Pattern A. . . .	4 0	41	37	45	48·97	50·92	0·66	1·0	132·50

Cox's ventilating gas stove consists of a vertical cylinder covered with a non-conducting substance, heated by luminous jets of gas, burning at the lower part, the fumes ascending into the interior and escaping at the back of the lower part. Fresh air from without is introduced at the lower part, separated from the gaseous fumes, and ascends and is heated in vertical tubes, from which it is collected in a perforated chamber at the top, whence it is discharged into the room.

Dr. Bond's Euthermic ventilating gas stove, Pattern B, consists of four concentric vertical cylinders, forming a central cylindrical chamber, and three annular spaces. Air from the room is admitted into the central chamber and the second annular chamber at the lower end, and ascends to the top, whence it escapes heated into the room. A ring-burner of atmospheric gas, on a swinging bracket, is placed at the lower end of the first annular chamber, the hot gaseous products ascend to the top, then descend by the outer annular chamber to the lower part, whence they pass off by the flue. The air passing through the stove becomes heated by conduction through the intervening cylinders. The outermost cylinder, or the casing, is corrugated in order to augment the external surface for radiation and conduction.

Dr. Bond's gas stove, Pattern A, may be described as follows:—Within an upright corrugated metal cylinder an inverted cone is fixed, into which fresh air is admitted at the lower and smaller end. The air ascends to the top, and is thence discharged into the room. Heat is supplied from an annular burner of atmospheric gas at the lower end, surrounding the inverted cone. The hot products rise and fill the casing surrounding the cone. They descend from the top through a number of tubes outside the casing, from the lower end of which they pass away into a flue. The air, in ascending within the inverted cone, becomes heated, whilst heat is also given off from the casing by radiation and conduction.

Gas fires require no attendance and create no dust in the room, but they are not, however, so economical in point of consumption as stoves which burn coal or coke, their effect depending mainly upon the amount of radiant heat which they are capable of producing, so that probably not more than one-third of the total heat produced by the combustion of the gas is made available in this form; nevertheless, a very fair effect is in some instances produced with a consumption of not more than 18 to 20 feet per hour. As a matter of course, gas used in this way cannot be so economical as solid fuel, with which it compares favourably only when the heat evolved by it can be completely utilised; and the desire of the public for a cheerful, clean, and at the same time economical fire has been sought to be met by combining with gas some form of solid fuel.

Amongst the more prominent of these is Dr. Siemens' gas and coke fire. There were several exhibited at the Smoke Abatement Exhibition. The following is the form exhibited by Messrs. Waddell and Main:—The back of the fireplace is covered by a wall-plate of copper, reaching half above the floor-plate of the fire and half below. The floor-plate, or "dead-plate," is riveted to the wall-plate, and stops short about an inch from the front bars. Into this interval a half-inch gas-pipe is laid, drilled with one-sixteenth of an inch holes, one and a half inches apart at the upper side, inclining inwards at an angle of 50° with the vertical. A supply of heated air for combustion is provided by the insertion of a kneed iron plate, under the dead-plate and near the wall-plate, so as to form a kneed channel, one inch wide, through which the air ascends at the back, and then passes horizontally to the front, where it meets the jets of gas. The air is heated on its way through the passage thus provided for it, and the heating-surface is augmented by the insertion of a corrugated sheet of copper in the vertical part of the passage, subdividing it into channels; so much so that the air, it is said, can be raised to upwards of 600° F. of temperature. The flame and hot products play upon and are dispersed in the body of coke laid upon the dead-plate, the coke is thus ignited and becomes incandescent. After it becomes thoroughly ignited the gas may be turned off. The following table shows the results of Mr. D. K. Clark's trials of the two Siemens' gas and coke fires to which prizes were awarded.

Name of Exhibitor.	Name of Apparatus.	Time under Trial.	Fuel Consumed.				Quantity of Gas Consumed.	Temperature.					
			Description.	Weight.	Ash.	Per cent.		External Average.	At walls 6ft. high.			Difference due to radiation 6ft. from fire, 5ft. high.	
									At commencement.	Total Average.	Average last hour.	Total Average.	Average last hour.
		h.m.		lb. oz.	lb. oz.		cub. ft.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
Waddell & Main.	Dr. Siemens' Gas and Coke Fire	4 0	Coke . . Anthracite	7 4 6 2	1 2	8 41	25·3	48	48·50	51·65	57·75	11·40	17·67
G. Wright & Co.	Ditto, Ditto, with Wright's Bivalve	5 0	Wood . . Coke . .	0 8 9 12	—	—	29	48	48	52·82	55·83	14·18	19·33

From the Jurors' report made on these fires at the Smoke Abatement Exhibition, it did not appear that any distinct advantage is the result of such a combination beyond the fact that, by the occasional aid of a gas-flame, the combustion of coke

may be sustained much more satisfactorily and under less favourable conditions as regards draught than would be the case without gas.

Other forms of gas fires devised for giving off radiant heat are made with asbestos. Of these we may mention Hislop's metallic gas fire. A fire-clay hollow backing, in which iron is mixed to give durability, is placed on a solid floor-plate, and is covered with asbestos in pieces. Gas is admitted within the backing, and is discharged through numerous small orifices into the body of asbestos, where it burns, the asbestos being raised to incandescence. S. Leoni and Co.'s gas and asbestos fire is adapted to an ordinary grate. A fire-clay back is inserted, also a fire-clay front tile, behind the bars and a little clear of them. The space between the two tiles is filled with asbestos, which is heated by atmospheric flames introduced from below. A sheet of atmospheric gas is burned against the face of the front tile, which is trimmed with asbestos, and becomes highly heated and radiates heat into the room.

S. Leoni and Co. also have an incandescent radiator gas fire. A fire-tile in an iron frame is hung on the front bars of a grate, trimmed with asbestos on the face, and heated by atmospheric gas from the lower edge. The results of the trials of this fire are as follows :—

Name of Exhibitor.	Name of Apparatus.	Time under Trial.	Quantity of Gas Consumed.	Temperature.					
				External Average.	At walls 6ft. high.			Difference due to radiation 6ft. from fire, 5ft. high.	
					At commencement.	Total Average.	Average last hour.	Total Average.	Average last hour.
		h. m.	cub. ft.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
S. Leoni & Co.	Gas Fire	4 0	71	51	52·25	56·47	58·75	8·0	11 34

There has recently been introduced a gas stove, called the Lux Calor stove, constructed as follows :—One or two hollow columns or tubes, on a hollow base, support a hollow chamber at the top. One or two jets of gas burn near the upper part, from which the gaseous products are conducted into the upper chamber, whence they pass down inside the columns. The products are cooled, and partially condensed, collecting at the bottom, where the remaining gas is passed off behind into the room; as, in the opinion of the inventors, there is no flue required.

The following is the test of this stove by Mr. D. K. Clark :—

Time under trial.	Quantity of Gas consumed.	Temperature.					
		External Average.	At walls 6ft. high.			Difference due to radiation 6ft. from fire, 5ft. high.	
			At commencement.	Total Average.	Average last hour.	Total Average.	Average last hour.
h. m. 4 0	cubic ft. 34	Deg. F. 46	Deg. F. 51	Deg. F. 55·67	Deg. F. 57·09	Deg. F. 3·34	Deg. F. 3·67

It is claimed for this stove that it can be used in a room to supersede a coil of hot-water pipes. There is no doubt that a proportion of the deleterious matter evolved in combustion is condensed, yet as the combustion takes place entirely in the room, without any communication with the outside, its use cannot be recommended except in places where there is a considerable change of air.

Gas stoves have also been proposed, in which the products of combustion are passed through layers of lime, rusted iron, and other materials, so as to absorb their deleterious compounds. Such stoves may possibly be successfully adapted to

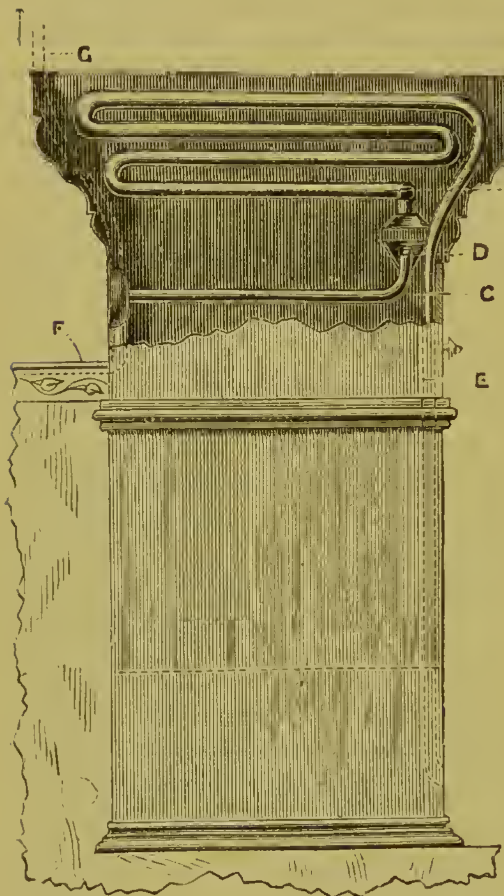


Fig. 231.

A is the top of the tube, made of iron or zinc to render it fire-proof; B, the coil, C, an air-burner; D, a shield perforated at the bottom to prevent the current of air passing up the tube affecting the flame; E, the pipe to carry off the products of combustion; F, three-eighths gas-pipe, led from the most convenient source to supply the air-burner; G shows the gas-pipe brought down from a bracket.

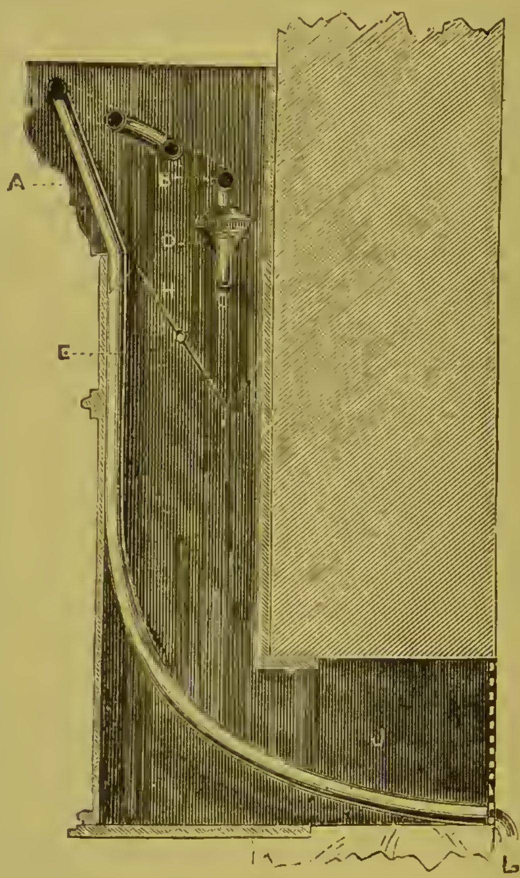


Fig. 232.

Diagram No. 232:—H, regulating-valve in tube; J, air-hole cut through the wall; cast-iron grating; L, mouth of pipe for carrying off the products of combustion; dimensions of the air-tube, 20 in. by 9 in. and 42 in.

warming rooms under special conditions; but, as a broad principle, it may be said that no stove is safe which does not provide for the complete removal of the products of combustion from the occupied space it is designed to warm.

In this connection may be mentioned a method of heating a supply of fresh air for rooms by means of gas, proposed by Mr. Boyle, and recently put in operation in the Council-chamber at the Guildhall.

It consists of a coil of pipe placed in the top part of a vertical tube, as shown in the annexed Figs. 231 and 232.

The action of this ventilator at the Guildhall may be described as follows :—The air is extracted from the ceiling of the Council-chamber by means of some of Mr. Boyle's ventilating cowls; whilst the fresh air to replace that so extracted is supplied as follows :—On the south side of the chamber four vertical air-tubes or brackets are fixed against the wall, two 2 ft. by $2\frac{1}{2}$ in. by 3 ft., the other two placed a little higher up in the wall, being 1 ft. 6 in. by 4 in. by 2 ft. These tubes communicate with holes cut through the walls, 2 ft. by 8 in., finished with cast-iron gratings. These air inlets are all fitted with Messrs. Boyle's patent heaters for warming the supply of air to any temperature required as it passes into the building; the north wall is similarly treated to the south, with the exception of having an extra tube at the end where the Lord Mayor sits. At the public end of the chamber three inlet-tubes are fixed, one at each side and one in the centre, also fitted with the air-warming arrangement. An abundant supply of air is admitted through these tubes, and tests have shown that the air can be warmed in cold weather to a temperature of from 60° to 120°, thus preventing cold draughts.

This plan of warming the air admitted into rooms is undoubtedly simple; and if, as it is understood, it can be arranged that the products of combustion be entirely cut off from the possibility of passing into the air entering the room, it would be a very convenient and useful arrangement under certain circumstances.

The experiments made by Mr. D. K. Clark, for the Smoke Abatement Committee, on heating by gas, showed that the rise of temperature per ten cubic feet of gas per hour was 2° Fahrenheit. Therefore, taking the cost for gas at 3s. 6d. per 1,000 cubic feet, the cost per ten cubic feet per hour would amount to 0·42d., capable of raising the average temperature 2° Fahrenheit.

To compare the cost of heating by gas with the cost of heating by coal, the average rise of temperature per pound of Wallsend coal consumed per hour was found to be 4·14°; say 2° per half-pound of coal per hour. Allowing 20s. per ton as the cost of coal, the cost of half a pound would be 0·107d., against 0·42d., the cost of gas doing equal duties.

There was a comparative test made at the Smoke Abatement Exhibition by Mr. D. K. Clark, of a hot-water apparatus for warming greenhouses, exhibited by Messrs. Hocking, Franklin, and Co., in which the effect of using gas was contrasted with the use of coke. This apparatus consisted of a small stove, connected with two circuit lines of cast-iron pipes, through which the heated water circulated, leaving the stove at the upper part and returning to it at the lower part, after having twice made the circuit of the room. The boiler is vertical, of the form of a truncated cone, made with a shell and a fire-box, inclosing a $1\frac{1}{2}$ inch water-space for the circulation of water. It is $18\frac{3}{4}$ inches in diameter at the bottom, and 13 inches at the top. The grate is circular, 14 inches in diameter. The boiler stands on an ash-box. It is fed from a hopper, consisting of a cylinder 15 inches in diameter and 24 inches deep, placed on the top of the boiler, delivering into an 8-inch tube, depending into the boiler for two-thirds of the depth, and surrounded by a water-jacket. The upper cylinder is only employed for long periods of heating. The burnt gases escape direct from the upper part by a flue to the chimney. The circulating-pipes are 3 inches in diameter inside, and have a total length of $160\frac{1}{2}$ feet, presenting on the outside $136\frac{1}{2}$ square feet of area for warming by conduction and radiation. The

coils are $5\frac{1}{2}$ inches apart between their centre lines, and the centre of the lower coil is 11 inches above the floor.

For the test, 2 lb. of wood and 114 lb. of gas coke were consumed in $45\frac{1}{2}$ hours. the consumption of coke being at the rate of $2\frac{1}{2}$ lb. per hour.

The same system of warming-pipes was heated by gas, which was burned in a cylindrical vertical boiler, in which the burnt gases rise through a central cylinder, water-jacketed, and through annular spaces surrounding it, into the upper part, whence they escape into the flue. The test lasted 6 hours 40 minutes, with a consumption of 330 cubic feet of gas, being at the rate of about 50 cubic feet per hour.

	Rise of Temperature. Deg. Fahr.
Hoeking Apparatus, with hot-water pipes, per lb. of fuel	2·90
" " " per 10 eubic feet of gas . .	3·0
Other Gas-heating Stoves, per 10 eubic feet of gas	2·0

CHAPTER LVII.

HEATING BY HOT WATER AND STEAM—GENERAL OBSERVATIONS ON THE RETENTION OF HEAT IN HOUSES.

Hot-water pipes and steam-pipes are very convenient for warming air; hot-water pipes are free from many of the objections arising from the direct application of heat to iron, because the heat can be regulated with exactness. The higher the temperature of the pipes, the greater is the effect in warming air.

Water boils at 212° Fahrenheit under the atmospheric pressure of 14·7 lb. per square inch, or 30 inches of mercury, *i.e.*, at about the sea-level. Under one-half that pressure, viz., 7·3 lb. per square inch, or 15 inches of mercury, it boils at 180°; under a pressure of 44 lb. per square inch it boils at 291°; and under a pressure of 132 lb. per square inch it boils at 357° Fahrenheit. Thus, a high temperature may be obtained from water without generating steam by heating it under pressure. Salt water, saturated with 41·2 lb. of salt per 100 lb. of water, boils at 227°, and freezes at about the zero of Fahrenheit.

There are a few points connected with the heating of water which should be alluded to.

The heating-vessels of hot-water warming-apparatus are not "boilers" in the ordinary acceptation of the term. They are simply that part of the system of circulation to which the action of the prime mover, heat, is applied; and they differ essentially from steam-boilers in that their contents ought not to "boil." The construction of a hot-water apparatus boiler should promote such a rapid circulation of the water through it that the heated water leaves it before reaching the temperature at which steam should be formed. The formation of steam would interfere with the circulation of the water in a hot-water warming-apparatus, and it is only when the circulation is impeded that ebullition takes place.

As no steam is intended to be formed, it is unnecessary to provide steam-room in the boiler of a hot-water apparatus, and the entire capacity of these boilers in proportion to their surfaces and area of fire-grate may therefore be less than in steam-boilers. With a sufficiently free circulation, the "capacity" is of less importance than the extent of surface presented for the reception of heat. The boilers of hot-water apparatus being always full of water and the water being in constant circulation, there is no direct relation between the capacity of a boiler and the quantity of pipe it is capable of heating; but on the other hand, the economical effect of a boiler is closely connected with the proportionate extent of surface which it presents for the reception of heat, as compared with the surface of pipes which give out heat.

Any estimate of the efficiency of a boiler depends upon the assumption that the form of the boiler is such that the surfaces are favourably disposed for the reception of heat and its communication to the water, and that its interior shape permits free circulation in every part. The position of the surfaces should be such as to allow the cooler water free access to the plates, and the readiest escape of those particles

which are heated, without materially interfering with each other. In this respect, perfectly horizontal surfaces are not so good.

Boilers of complicated construction are objectionable on account of the impediments they present to the free circulation of the water.

The "surface" of a boiler relative to the area of the fire-grate, and the extent of the pipe to be heated, is the measure of its power. The extent of the pipe which can be heated by any boiler, depends, other circumstances being alike, on the quantity of coal which can be economically burnt in its furnace; and the economical use of the coal can only be ensured by giving a due development to the recipient surfaces which take up the heat from the fuel and communicate it to the water.

On the average, a fair economical effect may be obtained from hot-water boilers by giving them from ten to twelve feet of heated surface for each foot of fire-grate.

With the surfaces properly disposed for the reception and communication of heat, one foot of boiler-surface is generally assumed, in round numbers, to heat from 27 to 30 feet of 4-inch pipe, or 30 to 35 feet superficial.

The efficient action of hot-water pipes depends upon the upward flow of the heated and expanded water, as it passes from the boiler, being made as direct as possible, and so protected as to lose little heat between the boiler and the place where the heat is to be utilised. The return-pipe, which brings the water after it has been cooled down by the abstraction of heat in warming the air, should be passed in to the bottom of the boiler as directly, and in as uniform a line from the place where the heat has been used, as possible. The velocity of flow in the pipes will depend upon the temperature at which the water leaves the boiler, the height to which the heated water has to rise, and the temperature at which it passes down the return-pipe back into the boiler. The efficiency of a hot-water apparatus will be regulated by these conditions, by the sizes of the pipe, and by such other conditions as affect the flow of water in pipes.

It is therefore especially necessary, in applying this source of warming, to have the advice of persons practically conversant with the question, and not to trust to theoretical views alone.

It will be evident that to obtain an equal velocity of flow when the height of the vertical column is small, the temperature at which the water returns to the boiler must be lower than when the vertical column is long. Therefore, when the boiler or source of heat is very near the level of the pipes for heating the air, the average temperature which can be obtained in the pipes will be lower than when the vertical column is long. Hence, the heating-surface and grate-area of the boiler, and the surface of pipe which enables the heat from the boiler to be utilised, must be regulated with reference to this difference of level.

It may further be assumed that with small pipes, the temperature being constant, the velocity of flow in the pipe necessary to furnish a given amount of heat will vary in the ratio of the length of the pipe.

When the water is under ordinary atmospheric pressure, and circulates through the pipes by virtue of the difference of temperature of the flow and return currents only, it is impossible to count upon a greater mean temperature of the pipes than from 160° to 180°, because above that temperature the water in the boiler begins to boil, and causes an overflow of the supply-cistern and escape of steam at the air-

pipes. In order to obtain a sufficient velocity of circulation for long distances, or with small differences of level, a forced circulation may be resorted to, as has been done by Messrs. Easton and Anderson at the County Lunatic Asylum at Banstead.

There two pipes are laid side by side, one of which communicates with the boilers, and is termed the flow-pipe; the other, termed the return-pipe, is connected with the feed-cistern for the boilers, which cistern is situated above the level of the boilers. Both pipes are connected with the various coils to which the heated water is desired to be conveyed by valves, which can be opened or closed at will. An Archimedean screw-pump is fixed on the return-pipe near the point where the pipe ascends into the cistern. This pump is always kept at work. When the communications between the flow and return-pipes are closed, the screw simply slips through the water; as soon as any communication is opened, the screw draws the water along the pipe and forces it into the cistern, thus ensuring a constant circulation.

Heating by hot water under pressure has been largely carried out by Messrs. Perkins.

By the Perkins system, the water is heated under considerable pressure, and a higher temperature is thus obtainable than with ordinary pressures.

In its simplest form the apparatus consists of a continuous or endless iron tube of about one inch diameter, closed in all parts, and filled with water. The joints are screw joints, connected within a socket forming a right and left hand screw. About one-sixth part of the tube is coiled in any suitable form and placed in the furnace, and the other five-sixths, forming the surface which gives out the heat thus communicated to the water, are heated by the circulation of the water which flows from the top of this coil; and, cooling in its progress through the building, returns to the bottom of the coil to be re-heated.

Water, when heated from about 40° to 212° Fahrenheit, expands about 5 per cent., and it requires about 28,000 lb. to the square inch to compress water 5 per cent. of its bulk. Hence, a tube called an expansion-tube is placed above the highest level of the smaller tubes which convey the heat to the distant parts of the building. This tube is of larger diameter than those used as heating-surfaces, and its length and capacity are proportioned to the quantity of tube to which it is attached.

The filling-tube of the apparatus is placed on a level with the bottom of this expansion-tube so as perfectly to fill all the small tubes, and yet prevent the possibility of filling the expansion-tube itself. The expansion-tube, being then left empty, allows the water, as it becomes heated, to expand without endangering the bursting of the smaller tubes.

The apparatus is filled by an opening connected with the lowest line of tubing, so that the water, as it rises, drives the air before it, and out through an opening in the expansion-tube. Great care must be taken to expel all air from the pipes by repeatedly forcing water through them. When the pipes are filled, both the opening in the filling-tubes and the opening in the expansion-tube are closed by screw plugs.

The form and size of the furnace varies according to the locality and the work the pipes have to do.

A temperature of as much as 300° Fahrenheit can be obtained in the tubes.

Theoretically this apparatus would go on for an unlimited time without requiring attention, because there would be no loss of water from evaporation, and as the water is not changed, and as most of the oxygen it contains is removed from the air in the process of filtering, there is no oxidation or rusting of the pipes. There are houses where the system has been in use for some years without requiring attention.

The use of steam for heating pipes possesses a similar advantage to hot water under pressure—viz., it affords a high temperature in the pipes; and when the object is to warm air, the higher the temperature of the pipes the greater is the comparative effect. Thus pipes heated by hot water under pressure convey heat to the air with greater rapidity than pipes heated by hot water at low pressures; and steam-pipes are more effective than hot-water pipes; and steam at a high pressure is more effective than low-pressure steam.

In heating by steam or by water under considerable pressure instead of by water at the ordinary pressure, there is the advantage that the high temperature obtained in the pipes causes the consequent radiation of a large proportion of heat to the walls of a room.

The conditions to be followed in the form and construction of steam-boilers are somewhat different from those for hot-water boilers; but their consideration is beyond the limits of this paper.

Heating by steam has been largely resorted to in the United States of America; and to be seen to perfection it must be studied there.

The following are, however, some of the chief points to be considered.

In warming a room by direct radiation, it is found that the best plan to secure equable temperature is to place the radiators or coils of steam-pipes near an inner wall; the warmed air passes up to the ceiling and cools against the outside wall and windows, and thus a circulation is maintained.

Where systematic ventilation is carried out in conjunction with warming, the regulation of the warmth to be supplied by the apparatus can be effected by dividing the coil into independent sections, one or more of which can be shut off at pleasure.

But in combination with systematic ventilation the warming is controlled by so arranging the casing or chamber containing the coil, that the whole or any part of the fresh air entering can be made either to pass through the coil and be warmed, or to "by-pass" the coil and escape warming; the warmed and unwarmed currents are then mingled in a mixing-chamber or flue, whence a supply of fresh air suitably tempered flows into the room.

In the construction of the apparatus, the prevailing practice in America is to employ wrought-iron welded tubes, not only for the mains, but also to a large extent for the radiating-surfaces that diffuse the heat. The separate lengths of tubes are connected by wrought-iron couplings when in the same straight line, and when not so, by cast-iron elbows, tees, branch-pieces, and return-bends. The so-called coils or radiators usually employed for diffusing the heat are compact nests of tubes, sometimes arranged vertically by having their bottom ends screwed into a cast-iron box, and at other times placed horizontally and connected together by branch-tees and return-bends.

In the use of these tubes, the essential feature of practical importance is the employment of tapering screw-threads, externally upon the tube-ends and internally

within the sockets of the couplings or fittings, as the means of securing durable steam-tight joints, which can be readily made or unmade.

Most frequently the steam for warming in America is supplied by one or more horizontal tubular or Seguin* boilers, set in brickwork.

The original Seguin boiler consists of a horizontal cylindrical shell, containing tubes in the lower half, with a steam-dome on the top; the tubes are arranged in vertical and horizontal rows, not alternating or zigzag; and the best practice is to place a man-hole in the front end over the fire-door, and beneath the tubes. The boiler is fired underneath, and the products of combustion return through the tubes from the back to the front, and then pass back again over the top of the boiler, which is covered in with brickwork; the temperature of this top flue rarely exceeds 400° Fahr. The fuel used is anthracite coal, yielding 8 to 12 per cent. of ash; and when well supplied with air it evaporates from $8\frac{1}{2}$ to 9 lb. of water per lb. of coal.

In regard to the circulation of steam, there are two methods of warming with steam, one with live steam direct from the boiler, and the other with exhaust steam. These two are frequently carried out in combination, and, in fact, generally so where exhaust steam is used at all for warming.

The cause producing the circulation throughout the pipes of the warming-apparatus is the difference of pressure which results from the more or less rapid condensation of the steam in contact with the radiating-surfaces; a partial vacuum of greater or less amount is thereby formed within the radiating portions of the apparatus, and the column of steam or of water equivalent to this diminution of pressure constitutes the effective head producing the flow of steam from the boiler, while the return current of condensed water is determined by the downward inclination of the pipes for the return course.

The whole details of the arrangements for steam heating have been worked out with great care in America, and a very clear explanation of these details will be found in the proceedings of the Institution of Civil Engineers, communicated by the late Mr. Robert Briggs, to whose skill many of the details of the present system of steam heating in America have been due.

The great advantage of steam heating is that the high temperature of the radiators or coils gives out radiant heat, which warms the walls and furniture in the same way as, though to a much less degree than, an open fire; and, moreover, the heat is got up very rapidly in a room. And, when desired, the apparatus cools down with equal rapidity when the steam is shut off. With hot water, on the other hand, it takes some time to heat up the pipes, and a considerable time to cool them down again.

The temperature of steam-heated surfaces for steam at 40 to 60 pounds pressure will run from 290 degrees to 310 degrees; and these temperatures are practically uncontrollable whenever the steam is admitted to any coil or radiator; so that the external surface of the coil or radiator in air is sensibly the same—290 degrees to 310 degrees. Some slight but unreliable reduction of temperature in the steam may be had by throttling the supply-pipe, but this method becomes especially unreliable when the condensed water is returned, without

* Introduced in France about 1826 to 1830 by M. Seguin, engineer of the St. Etienne and Lyons Railway; and in America about 1844 by Mr. Nason.

trapping, at the same pressure to the boiler. Coils give off heat determinately until the last moment of being shut off. They fill with water, and become very noisy with water hammers when a small volume of steam in some way is interposed between two columns of cooled water that instantaneously condenses it and forms a vacuum, bringing such columns into solid contact with each other. In exposed places throttled coils freeze up. The nicest adjustment may secure the end of lower temperatures of surfaces, and corresponding lower temperatures of air-currents passing them, or of desired constant temperature of air-current, obtained by giving less heat to a warmer entering air; but the least change of boiler-pressure disturbs it all; in a moment the coil is virulently active with heat, or obstinately passive by water-clogging.

There are two methods of meeting this difficulty. The first is the division of a coil into sections, so that one or more of the sections can be employed in heating, or be shut off at will.

The second method is called the by-pass, and is arranged by passing around the coil, unwarmed, such part of the current of entering air as will reduce or temper down that remainder of the current which is permitted to pass through the coil, and is heated by contact with the heated surfaces. A comparatively simple arrangement of the casing of the coil, with register or louvre valves, and some baffling contrivance, will secure the admixture of the two currents.

In one essential regard, the by-passing method is more efficient than the other, because it gives an instantaneous change of temperature of the air delivered in the rooms, while the sectional method calls for time to elapse until the closed-off sections shall have lost their heat, or the newly-opened ones increased in temperature, before any effect is produced on the temperature of the air.

In order to obviate the inconvenience above mentioned, viz., that the steam frequently makes unpleasant noises if air or water lodges in the pipes, it is advisable in designing apparatus for steam heating in a building, that the flow-pipe should be carried in as direct a line as possible from the boiler to the highest point, and that all coils for heating should be placed on the return-pipe, which should be laid in a uniformly descending line, so arranged as to prevent the lodgment of any condensed water. Heating by steam requires much consideration to make it a pleasant means of warming rooms, because the heat given out is very great, and, unless it is combined with the supply of fresh, and the removal of vitiated, air in such a manner as an open fire affords, it becomes often oppressive. The temperature of the pipes cannot be regulated as with hot water; the way to obviate this objection has been already mentioned. There is also a plan of using expansion steam—*i.e.*, driving all air out of the coils—a principle which may be described as the reverse of Perkins with hot water. In this case the vapour of water which passes off before the water boils will fill the pipes and warm them to a temperature of from 190° to 210°.

There may be some practical inconvenience attending the use of high-pressure steam in localities where an experienced workman is not near at hand. For this reason hot-water pipes have been generally preferred for warming ordinary houses in this country.

The shape of pipes for heating by means of either hot water or steam has an influence on their capacity for heating. The usual form is that of circular pipes,

probably mainly because of their greater strength, and the facility with which pipes of this form are made and fixed.

Sylvester proposed a form of pipes, which was continued by Messrs. Rosser and Russell, in which the heating surface was supplemented by flanges as shown by the annexed section (Fig. 233); but the greater convenience of the circular form appears to have prevented the more general adoption of flanged pipes.

In the heating-apparatus of the Houses of Parliament, pipes are used whose heating-surface is increased in certain places by means of numerous flanges placed at right angles to the run of the pipe.

In connection with the use of hot water in steam-boilers, some observations are necessary upon the best means for preventing smoke. The Committee of the Smoke Abatement Exhibition expressed great regret that no form of boiler-furnace was submitted to them in which fuel is converted into gas before it is used for heating the boiler. They further pointed out that mechanical appliances for feeding the fires under boilers may readily be adjusted so as to meet the changing needs and conditions of the furnace, and that they are less costly than the skilled labour required to produce comparable results by hand-firing.

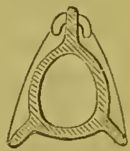


Fig. 233.

Mechanical stokers, as the name implies, are designed with the following objects: viz., the substitution of mechanical power for the manual labour of the stoker, the delivery of a small and continuous supply of fuel to the furnace in the place of the larger quantities cast in by hand from time to time as required, and the constant movement of the fire-bars, by which the adhesion of masses of clinker to the bars is prevented, thus permitting at all times the free access of air beneath the fire to promote combustion.

The use of mechanical stokers is of the greatest importance in abating smoke. Not only is the saving of labour very considerable, and the saving of fuel marked, but in nearly all the forms shown in the Exhibition and tested while in operation, smoke during their working was either entirely avoided, or much reduced in amount.

But no doubt these appliances are still open to much improvement.

When the form and description of apparatus for heating has been decided on, the amount of heating-surface to be afforded for purposes of ventilation and warming depends mainly upon the volume of air to be admitted and removed, and the temperature desired to be maintained; but in any given building there are other circumstances to be taken into account—viz., the position, aspect, subsoil, temperature of locality (for instance, a cold dry climate like Canada requires very different means of warming from what is necessary in mild damp England), the shape and size of building, extent, position, and thickness of walls, size and form of windows, skylights, and such like matters, which affect either the temperature of the incoming air or the conditions which determine the loss of heat in a building; but in order to ascertain accurately the quantity of pipe required to heat any building frequently involves complicated calculations, the formulæ for which would be out of place here. For the purpose of an ordinary approximation, the buildings with which the hot-water engineer has to deal may be divided into two classes: firstly, those in which the surface exposed to the cooling influence of the atmosphere is either by its nature or extent a more important element than the cubic contents; secondly,

that class of buildings in which the cubic capacity and the ventilation are the most important.

Mr. Hood, whose valuable treatise on warming and ventilation is well known, considers that the average rate of cooling for each foot of glass-surface exposed to the external atmosphere is equivalent to about $1\frac{1}{3}$ cubic feet of air, cooled as many degrees per minute as the internal temperature exceeds that of the external air—thus, if the difference between the internal temperature of a greenhouse and the outer air were 30°, then as much of the interior heat as is equivalent to $1\frac{1}{3}$ cubic feet of air cooled 30°, would be transmitted by every superficial foot of surface.

At the mean temperature of hot-water pipes, one square foot of pipe-surface is equal to warm about $6\frac{1}{2}$ cubic feet of air 30° per minute; whence it results that one foot of pipe would be required for every 5 feet of glass-surface when the difference of temperature is 30°.

If the temperature of the house were to be maintained at 60° above that of the external air, double the quantity of pipe would be required, supposing its surface to remain equally effective; but as in this case the difference between the temperature of the pipe and the surrounding medium would be less, rather less heat would be given off per foot of pipe-surface. As an approximation, however, we may say that for houses maintained at 60° above the external air, one foot of pipe should be provided for every $2\frac{1}{2}$ feet of glass.

The second class comprises buildings of which the cubic contents are large in proportion to their enclosing surfaces, in which the loss of heat by transmission through their walls is comparatively inconsiderable, the absorption and retention of heat by their solid materials great, and in which the air is not changed so frequently as to exercise a material influence upon the temperature.

It is true that when once the air of any large building is raised to its normal temperature, no more heat need be generated by the warming-apparatus than is required to compensate for the loss by transmission through the walls, &c., and by the ventilation. In most cases, however, the power required to warm the air of the building in the first instance, and its solid materials, is so great, that these become important elements in calculating the power of the apparatus.

There will, of course, be a considerable addition to be made for the air required to be removed for ventilation. This depends on the conditions alluded to elsewhere. To the extent to which this takes place must a further allowance for heating-surface be made.

Mr. Hood further shows that 1 foot in length of 4-inch pipe at an excess of 125° above the surrounding air will raise the temperature of 222 cubic feet of air 1° per minute, equivalent to about 190 feet per superficial foot of pipe-surface.

In order, then, to ascertain the extent of pipe necessary to heat the *air* of any building, we have to multiply its cubic contents by the number of degrees which the air is to be raised; and the product divided by 190 into the time in minutes within which the effect is to be attained will give the number of superficial feet of heating-surface required to warm the air. There would be an addition for counteracting the cooling-surface of the windows, skylights, roof, and walls.

Until the whole of the solid materials of the building were brought up to the temperature of the internal air, there would be a large absorption of heat; and as the capacity of solid bodies for heat is greater than that of air, the quantity of heat

absorbed, and the time occupied before an approximate equality of temperature could be attained, would be very great. Observations conducted with the object of ascertaining the quantity of heat taken up by the solid materials of some large buildings, such as churches, show that it is much greater than the quantity expended during the same time in warming the air and compensating for the loss by transmission.

There are one or two other matters bearing on the question of warming, on which some observations here are especially desirable, because sufficient attention is not paid to them.

One great cause of expense of fuel in English houses, and of the inconvenience experienced from draughts, arises from the loss of heat which takes place in consequence of thin walls, lightly-constructed roofs, thin glass windows and skylights.

The same carelessness in economising heat prevails in railway-carriages, and they afford a ready illustration of what takes place, because the effects are so striking in cold weather. The floor and roof of a railway-carriage, instead of being double, with air-spaces between, are single; consequently the radiation of heat from them is very rapid. In cold weather the heat generated by the persons present and by the foot-warmers is insufficient to keep up the temperature. If the roof and sides of a railway-carriage, and the floor, were made double, with an air-space between, the loss of heat by radiation would not much exceed half that with the present roofs and floors; and in summer the carriages would suffer proportionately less from sun-heat. The same is true of houses. If houses were constructed with thick walls with closed air-spaces in the centre, with double windows, and with the slates of the roof laid on close boarding covered with felt, they would retain the heat in winter far better than most houses now do. London houses with thin party-walls also illustrate this question. When a person occupies a house, and the two neighbouring houses are unoccupied, the heat generated in the house is so rapidly radiated through the walls into the neighbouring houses that it becomes very difficult to keep the house warm; whereas, when the houses on both sides are occupied, the warmth of the house is considerably increased.

The loss of heat from glazed roofs and ceilings, from skylights, and from metal roofs, such as are used in railway-stations, is very considerable.

The air in contact with metal or thin glass exposed to cooling influences is, in the case of a roof, under the most favourable condition for being cooled. Each layer, as it is cooled, falls down and is replaced by warm air, which undergoes the same process. This renders a space covered with a metal or glass roof without intermediate ceiling very difficult to warm. Therefore in halls or rooms lighted by a glass roof, or staircases lighted by skylights, it is essential for preserving the heat that there should be a second glass ceiling below the one exposed to the outer air; and in cold weather it may be advisable to adopt special means to warm the intermediate space, if an equable temperature is sought to be maintained in the room at all times. Where glazed ceilings are lighted by gas, with lights above the lower ceiling of glass, the heat from the gas when lighted is sufficient to keep up the temperature.

In very hot weather, when it is desired to cool down the temperature of an iron or glass roof, it may be watered by jets from 8 or 9 o'clock in the morning till about 5 o'clock in the evening. The quantity of water would, however, be considerable,

probably not less than about 25 gallons per hour per square of 100 feet. The practice of lime-whiting the roof, which is largely resorted to in some places, is a great protection against heat.

But we should not suffer so much either from summer heat or from winter cold in our houses if we built them with a greater regard to the means for preventing radiation of heat into and out of them; and this need not necessarily entail any greater expense in construction, but only greater thought on the part of the architect and builder.

CHAPTER LVIII.

Ventilation by Propulsion—Draughts—Distribution of Inlets and Exits for Air—Effects of Cooling-surfaces—Air-flues—Means of removing Impurities from Inflowing Air.

The next point for consideration is ventilation by means of the direct propulsion of the air.

Theoretically, the propulsion of air into a room would expel all the foul air through the cracks of windows and doors, even if no special apertures were made for its removal, and the existence of pressure in the room would tend to prevent draughts of cold air from doors and windows; but in practice, in the ventilation of hospital wards, the system of propulsion, *i.e.*, forcing the fresh air into the room, and allowing the vitiated air to find its way out, has not been generally found successful as a means of purifying the air. The air forced in seems to seek the first place of escape, and unless the system is combined with an efficient system of extraction, much of the vitiated air may remain in corners and dead angles. It is therefore generally advisable to combine with a system of propulsion for the inflowing air some method of extraction for vitiated air. Where the circumstances allow of it, it will be found simpler to dispense with propulsion, and to rely upon the action of extraction-shafts to draw in the air required through adequate channels provided for the ingress of fresh air. In cases, however, where a large volume of air is required to be passed continuously into a confined space, and the channels are limited in size, it may be found advisable to assist the movement of the inflowing air by propulsion.

Ventilation by propulsion requires the direct application of power to move the air. This is generally done by driving air by means of fans, worked by steam-engines, along channels in which the friction becomes an important consideration.

The friction of air varies as the square of the velocity multiplied by the pressure against the sides of the passage. This pressure being uniform, its total amount depends upon the total surface—that is, the length multiplied by the perimeter of the cross section. The force required to propel air through any passage is therefore equal to the square of the velocity into the total surface multiplied by the co-efficient of friction. It is beyond the limits of this treatise to discuss the various forms of fans for ventilation of buildings, because the use of fans in the ventilation of houses is limited to exceptional cases and generally on a small scale; those who wish to pursue the subject will find it fully discussed in the paper, and the discussion which followed, by Mr. Briggs, in the Proceedings of the Institution of Civil Engineers.

We may, however, mention that the best propellers have produced a useful effect of from 70 to 75 per cent. in proportion to the power employed.

Dr. Arnott proposed an apparatus on the principle of the gas-holder, by which he could carefully regulate the quantity of inflowing air. In the House of Commons there is an apparatus of this description, on the principle of a double-action piston, by which in the summer a given quantity of air cooled with ice can be forced into the House.

The Great Opera at Vienna is ventilated by extraction-shafts from the ceiling, heated by hot-water boilers and by the products of the gas chandelier, the admission of air being regulated by propulsion by a fan from below.

This method of ventilation—viz., by propulsion—was adopted on the recommendation of Mr. Van Hecke in the Hospital Necker at Paris. In an experiment made in two wards, one ventilated by propulsion and the other by extraction, but in both cases with closed windows, and no other apertures than those for ventilation, the ward ventilated by propulsion was cleared of the smell created by burning pastilles in fifty minutes with a volume of air injected equal to one-and-a quarter the cubic content of the ward; whilst with the ventilation by extraction it required seventy minutes to remove similar fumes and a slightly greater volume of air.

General Morin and others who have had the largest experience of ventilation, have, however, preferred the system of extraction to that of propulsion; nor has the system of ventilation by propulsion been extended in the Paris hospitals. Indeed, the hospitals where ventilation by propulsion has been tried have not been healthy. There is one practical reason which offers itself—viz., that experience of buildings such as hospitals, which require continuous ventilation, shows that on various occasions, either for repairs or for other reasons, the working of the fan is sometimes stopped; and during this period of cessation of course the ventilation becomes seriously defective. There are other obvious reasons. This system implies that the whole air which comes in or goes out shall do so independently of windows; that is to say, that the windows shall not be opened.

But if the impurities in a confined air-space are not uniformly diffused (and it is certain that they are not), then, unless the whole air is periodically swept out, some impurities remain long enough to attain a putrefactive state. In practice it is found to be necessary, at frequent intervals, to sweep out all the impure air in an inhabited building, and to begin again with fresh air.

This is especially the case with buildings occupied by many people; consequently in barracks and in hospitals it is of essential importance to place the windows opposite to each other, and to have rooms of such a width as to secure the due action of these sweeping-out currents.

The system of propulsion is, however, useful under special conditions, and especially when on temporary occasions and for limited periods it may be desirable or necessary to provide special means of ventilation.

The system of extraction by fans is of the highest value in places where it is desired to remove particular impurities with great rapidity; such, for instance, as in workshops where the dust of cotton, steel-filings, shavings, or injurious emanations produced locally, are sought to be removed at once.

In the Mont Cenis and St. Gothard tunnels, during construction, the compressed air, after having been utilised to work the boring-machines, escaped into the tunnel, and provided fresh air for ventilation.

Compressed air has also been applied to produce a current, and thus to extract vitiated air, somewhat on the principle of the steam-jet which causes the draught in a locomotive chimney, but acting by its momentum only. The system was used for the ventilation of some of the galleries of the Exhibition at Paris in 1867, and was subjected to experiment by General Morin; and he shows that the useful effect

varies inversely with the cube of the velocity of the air in the channel. This method of propelling air is not advantageous; but it may be resorted to in special cases where difficulties exist in applying other methods of propulsion.

Before illustrating the subject of ventilation with examples, it is desirable to mention a few general considerations which it is necessary to keep in mind.

One of the chief difficulties of ventilation arises from the draughts occasioned thereby.

Large rooms, in addition to the advantage afforded of enabling the air to be changed with more comfort to the occupants than small rooms, also present the advantage of a larger wall-surface, and of more numerous windows, which allow of a larger insensible ventilation; thus larger rooms will have, even in proportion to their occupants, an apparently less degree of impurity than small rooms. Although the uniform diffusion of carbonic acid is comparatively rapid in the air of a room, the organic emanations given out do not in practice diffuse themselves either rapidly or uniformly. They hang about in corners where there are obstructions to the flow of air, or near the ceiling, in which case they cool down and fall, and mix with the air of the room, thus increasing the impurities. Consequently, there is no advantage in mere height of a room unless combined with means for removing heated air from the upper part. Indeed, a lofty room with a space above the top of the windows or ventilating-openings to which air loaded with emanations can ascend, remain stagnant, cool, and then fall down, is a positive disadvantage.

The air of a room will be generally best renewed by means of open windows and doors, when these are so placed as to ensure a thorough draught; and open windows should always be resorted to when the weather permits.

In the hospitals specially erected for the wounded in the Franco-German war, the sides were constructed to lift up bodily, or to be removed, so that during mild weather the whole of the patients were in a kind of open shed, with fresh air always playing over them. Many cases brought into these hospitals from brick buildings, and suffering from gangrene and other hospital diseases, were cured by the fresh-air treatment; and the more the air of rooms can be renewed by means of open windows the better.

But the windows cannot always be kept open. In cold climates the windows must be closed to keep the rooms warm. In hot climates the windows may even sometimes have to be kept closed to keep the rooms cool. Moreover, windows are so placed in a room as to meet the requirements of light, and do not therefore necessarily occupy the most advantageous position for the continuous admission of air. Therefore every room should have special arrangements for the admission and extraction of air.

The more these various inlets and outlets are distributed about the room the better, because then there is less danger of stagnation in any one part of the room.

The fresh air should be obtained from places where there are no adjacent sources of impurity; especially not from the vicinity of ash-pits, manure-heaps, gully-gratings, or other sources of foul air. The inlets from the outer air should be at least two feet from the ground, and the surface near should be paved and sloped away from the inlet, so as to carry off wet rapidly. It has been estimated that the impurities of town air are very much diminished at 200 yards' height, and are not found above 600 yards in height—a London fog will rarely be perceptible at a height

of above 100 yards—consequently to bring pure air into the houses in a large town, the simplest way would be to draw it down from a height by means of a high shaft or tower.

The channels for the admission of air should, as a rule, be short; if they are long they should be direct, and accessible. Long channels are liable to collect dirt, and to form a refuge for insects. Hence, if it is necessary to make them long, they should be easily accessible for cleaning, as already mentioned. Deep underground channels and receptacles will modify materially the temperature of the inflowing air.

Underground channels should always be impervious to ground-air, and there are very few materials impervious to air.

The liability of air in underground channels to mix with ground-air would be diminished if the air were supplied to the channels or receptacles by propulsion, and retained in them under some pressure.

Underground channels should be perfectly dry. Damp channels overcharge the air with moisture; and this would interfere with the warming of the air; they induce the presence of animal and vegetable life, which dies and decays, and renders the air impure.

In towns where the atmosphere is full of particles of soot and other impurities, the inflowing air deposits these particles, and rapidly blackens any surface it impinges on. The impurities may be removed by passing the air through a filter made of cotton wool, laid lightly to a thickness of about half an inch, on a copper-wire frame. (See Figs. 234 and 235.)

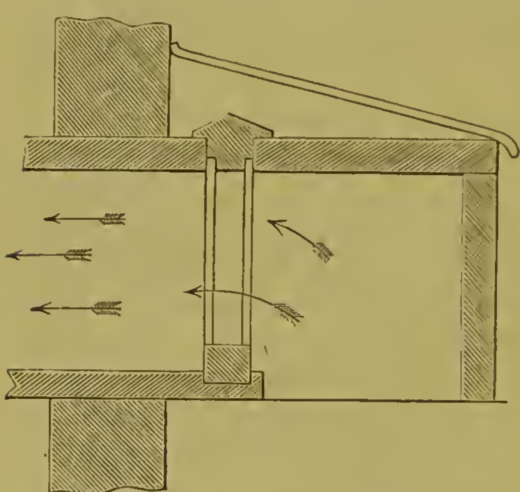


Fig. 234.—Section of entrance to fresh-air flue with cotton-wool filter.

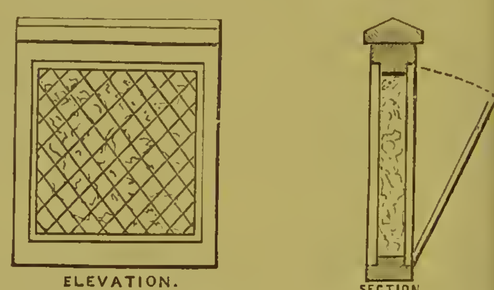


Fig. 235.—Frame to hold cotton wool.

The cotton wool must be renewed at intervals, dependent on the state of the atmosphere.

Sliced sponge acts equally as an air-filter, and may be easily washed, dried, and replaced.

A system has been introduced of endeavouring to remove impurities from the inflowing air by causing the current to come in contact with a surface of water. The best arrangement of this kind appears to be the one shown in the accompanying figure, 236. The air enters from the outside of the building, through the inlet in the external wall, passes up the shaft H, through the opening K; it is then sucked in by the water-spray, passes down the cylinder, B, and up through the shafts, M on plan, through the top of the apparatus into the room. This

arrangement would probably thoroughly wash fog and smoke out of the air in London. It must, however, be remembered that in damp weather the plan is liable to the inconvenience that the water keeps up the saturation of the air with moisture. A somewhat similar system has been adopted in some factories for preventing the smoke from polluting the atmosphere by passing it through a chamber filled with spray; a similar system would be useful for washing the impure air of towns.

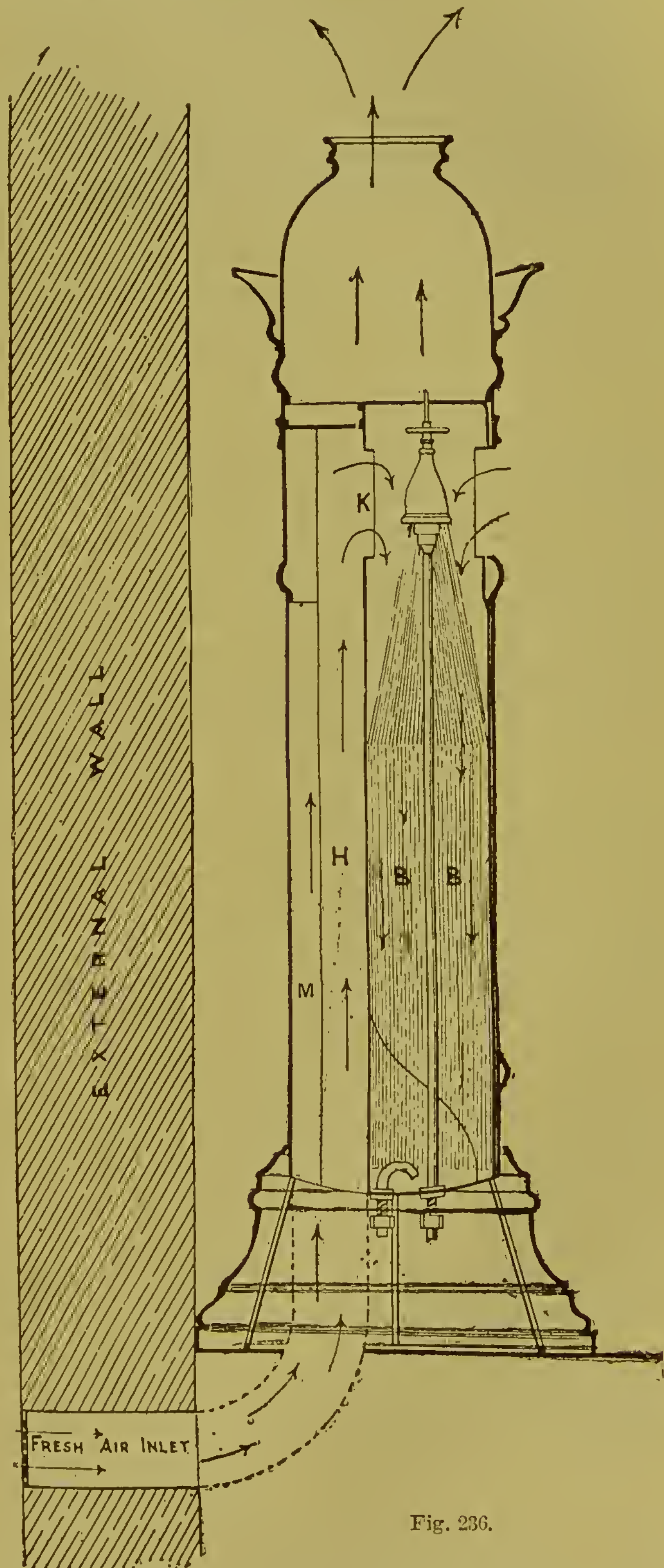


Fig. 236.

Extraction-shafts, when for ventilation only, should be placed so as not to occasion unpleasant draughts. It is advisable that, as far as possible, extraction-shafts from different rooms, the operation of which depends on temperature, should be independent of each other. Where the rate of extraction is sluggish and the temperature is low in the shaft, there may arise conditions in one room which may determine a reverse current, and then, when there is not a complete separation, the bad air from one room may be introduced into another room. Extraction-flues in which the temperature exceeds that of the outer air should always be arranged, if possible, to conduct the air upwards, so as to assist its flow. Every descent into the flue has to be compensated for in some way, either by extra height of shaft, temperature, or expenditure of force.

The best form for an extraction-flue is the circular form, because it affords a maximum of area with a minimum of perimeter, or surface, and therefore causes a minimum of friction.

By the best ventilating-arrangements we can only get air of a certain standard of impurity; and any ventilating-arrangements are only make-shifts to assist in remedying the evils to which we are exposed from the necessity of obtaining an atmosphere in our houses different in temperature from that of the outer air. To obtain that temperature we sacrifice purity of air; therefore, whenever the outer temperature permits it, windows should be widely opened, so as to replace the air of the room by fresh air as often as possible.

CHAPTER LIX.

Illustrations of Ventilation and Warming Houses—Dining-rooms—Smoking-rooms.

It is very difficult to illustrate the subject of ventilation and warming by means of instances of the best methods of warming and ventilation to be applied in practiee. Every house, and indeed almost every room, may require its own method of treatment, because the situation, the size, the shape, the materials used in eonstruction, the position of fireplace, of inlets sueh as windows, and outlets such as doors, vary in almost every house, and each of these has an important influence on the question.

The Roman plan was to warm the floor and walls by carefully-managed flues, which passed backwards and forwards under the floor, and which distributed the temperature equably under it. The floors were of tiles, and no doubt without this arrangement the cold would have been more severe than with a wooden floor; but this plan had also the advantage of preventing radiation from the bodies of the occupants, and of enabling them to breathe eool air. It ensured the keeping of the feet warm; possibly the practice of wearing sandals instead of woollen socks and shoes may have had some influence in determining this mode of warming. The fires were of wood or of wood charcoal, and the flues, therefore, were not so liable to be stopped up with soot as would have been the ease with coal.

The determination of the arrangement for warming and ventilating a house must depend upon the climate in which a house is plaeed, and on the size and position of the house. In a temperate elimate, like parts of Devonshire and Cornwall, a very different arrangement may be eonvenient from the one required at Liverpool or Norwich. Where the climate is usually temperate, and where really cold weather is exceptional, it may be more convenient to make each room self-contained as regards its manner of ventilation and warming, and to provide a reservoir of fresh warmed air in the stairease, passages, and halls, by means of ventilating fireplaees, stoves, or hot-water or steam-pipes, in convenient localities, to warm the incoming fresh air. In such eases, in each room a ventilating fire-plaee, combined with some simple form of outlet or shaft from the upper part of the room, will be sufficient. The use of a fireplace in every room undoubtedly gives some trouble in carrying eoals; and therefore, when on grounds of economy this is an important object to be avoided, the supply of heat from some central souree becomes of advantage. It depends upon many circumstanees whether any eeonomy in the quantity of eoal burned will result from supplying the heat for the whole house from one fire. When separate fires are used there is a large amount of saving in the fact that the fire is not always lighted, and that when it is lighted the heat from the direct rays afford a pleasanter method of heating than the warmed air of a room dependent upon other methods.

On this account the open fireplace has always held its own, as being the most convenient, as well as the most cheerful, means of warming and ventilating a room.

The open fireplaee is a most powerful engine of ventilation for drawing out the air.

In a house with a central staircase, in the case of the temperature of the house being greater than that of outside air, the staircase becomes a powerful shaft in which the air moves up with considerable velocity. It is often more powerful than the chimney-flue, because of its larger size, and thus it pulls air down the chimneys, and is often the cause of smoky chimneys. The open fires in the rooms require to be fed with fresh air, and it will frequently happen that the warm-air shaft of the central staircase will combine with the chimneys to draw in the air from every available opening. They will draw up the air from the basement; they will draw it, if they can, from the water-closet and sink-pipes, unless the water-closets and sinks are in projecting buildings cut off by lobbies ventilated from the outer air.

For these reasons it is of importance, not only to provide fresh air to the staircase, but when open fires are used, to make each room in which there is an open fireplace dependent on itself for its supply of fresh air. If the temperature of the room is to be kept up to a pleasant heat, this must be by warmed air.

The ventilating fireplace supplies its own warmed air; but when the fireplace is not adapted to supply warm fresh air to the room, the warmed air must be supplied from some central source of supply.

This air must not be drawn from the basement, because the basement may contain refuse, and in many houses it affords an opportunity for the air from the surrounding ground to pass into the house. This ground-air, in towns especially, is likely to be contaminated with escapes of gas from gaspipes or sewers, and should be cut off from the houses.

In order to prevent air from the basement passing into the house, the air-supply for the upper part of the house should be plentiful, and quite independent of the supply for the basement. Indeed, as proposed by Dr. Richardson, it would be very desirable to draw down the fresh air from the roof, if such a supply can be obtained free from soot.

Mr. Sylvester applied the principle of ventilation dependent upon open fireplaces many years ago in private houses. At a large country house in the midland counties, he brought the fresh air from a tower about twenty to thirty feet high, placed about fifty yards from the house, along an underground brick and cemented channel of three feet by two feet, to a chamber under the house on the level of the back yard, but below the living-rooms. Here it was warmed by numerous hot-water pipes, the temperature of which was never allowed to reach the boiling-point, because the heating-surface of the pipes was arranged to take away the heat more rapidly than the boiler generated it. The air passed thence into the hall, the back staircases, the corridors, and by flues in the walls up to each of the sitting-rooms and bed-rooms, so as to supply to each room warmed air in place of that removed by the fireplaces. The principle on which the warmed air was supplied was that its temperature should never exceed 54° to 56°, it being intended that the additional heat should be supplied by fireplaces in the rooms, which formed a necessary adjunct to this system of warming and ventilation, because by them the extraction of air from the rooms took place. The arrangement was such as to preserve an equable temperature and to prevent draughts.

The main principle of the arrangement was to retain the open fireplace and chimney as the extraction-outlet for every room, and by slightly opening a window

at the top of the staircase the warmed air in the corridors and staircase formed a continually-ascending current.

Messrs. Drysdale and Hayward have erected a house with the following arrangements for combined warming and ventilation which, as being founded on principles almost the direct opposite of the plans adopted by Mr. Sylvester, may be advantageously described here (Fig. 237).

The house consists of basement, ground floor, and first, second, and third floors. The basement (L) is devoted principally to the collection and warming of the fresh

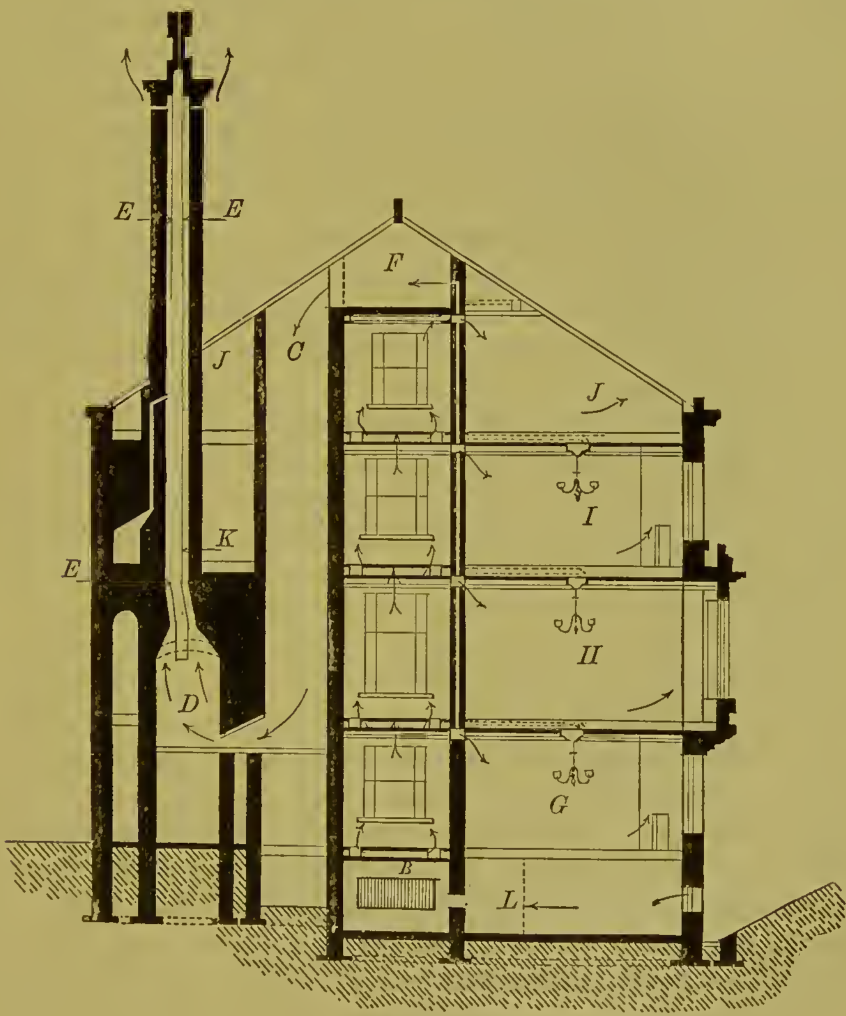


Fig. 237.

air. On the ground floor (G) are the cellars, a ball-room, two professional rooms, a gentlemen's cloak-room, and water-closet, and the main entrance, with vestibule and stairs, lobby, and servants' entrance and lobby. The first floor (II) is the living floor; on this is a drawing-room, with ladies' dressing-room and water-closet; a dining-room, with china-closet; and a kitchen, with cook's pantry, larder, scullery, and butler's pantry. The second floor (I) consists of the family bed-rooms (four), with breakfast-room, housemaid's closet, bath-room, and water-closet; and the third floor (J) of the servants' bed-rooms (four), with children's play-room, store-room, and two water-cistern rooms. And above, beneath the ridge of the roof, is the foul-air chamber (F), into

which the vitiated air of all the rooms of the house is collected, and from which it is drawn by the kitchen fire, by means of a shaft passing down to the ground floor, and then ascending behind the kitchen fire and up the kitchen chimney-stack round the smoke-flue. This feature of the arrangement is open to question, as it is to some extent a waste of power to draw the air from the top of the house down to the ground floor to be sent up the outlet-shaft behind the kitchen chimney.

The principal part of the house consists of a front and back block, each of about thirty-three feet by twenty feet, with a lobby nine feet wide between them, running north and south. This central lobby is the warmed-air corridor or ventilating-lobby; it is lighted by a window at its south end by day, and by Rickets's globes at night; and it is shut off at its north end from the main staircase, vestibule, and front entrance by vestibule doors. Out of it open all the principal rooms of the house.

The front entrance, with the vestibule and main staircase, twelve feet wide, are placed, not in the centre, but at the north end of the house.

The main staircase runs between the vestibule in front and the kitchen stairs behind, and is lighted by an ample skylight. The servants' entrance and lobby are behind the ventilating-lobby, and the servants' stairs run up between the main staircase in front and the kitchen behind. By this arrangement the lobby, into which opens the door that lets in the cold air, by being frequently opened, is shut off from that out of which the living-rooms open.

The central corridor serves as a lobby to the rooms on each floor.

Along the centre of the ceiling of each storey of the central corridor is an ornamental lattice-work, two feet wide, and along each side of the floor above is an iron grating, one foot wide; these allow the warmed air to ascend from the lobby beneath to the lobby above, but the floors check it for the supply of each storey, and prevent it from rising directly to the top one, as it would in a stairs lobby.

The incoming air is warmed by an apparatus on the high-pressure system, by which the pipes are heated to a high temperature. A Perkins furnace is fixed in the basement of the stairs lobby; the flow-pipe is carried up to and along the bed-room lobby; it is then brought down and along the picture-gallery; and after that, brought down to the opening in the ceiling of the basement of the central lobby, which it covers, running backwards and forwards the whole length ten times. Fresh air enters into the lower part of this basement, and, rising, is heated by the heated pipes, and then passes through into the lobby of the ground floor, and thence into the lobby of the first floor, and thence into that of the second floor, and thence into that of the third floor, so that the central corridor is filled from the ground floor to the attics with fresh warmed air, and may be kept permanently at 65°, or upwards, the winter through. Above the attic floor this corridor is continued up to the roof, and made into an air-tight chamber (F), under the ridge of the roof, to receive the outlets of vitiated air-flues from the different rooms of the house. Out of this central corridor all the principal rooms of the house open; and out of it, and out of it only, they receive their supply of fresh air. The cornice round the ceiling of this corridor, and that of each of the rooms opening out of it, has a lattice central enrichment, 7 inches deep, and the wall between these two cornices is perforated by as many 7 inch by 5 inch openings as the joists will allow, so that the fresh air has a free passage from the corridor into the rooms, even when the doors are shut. The drawing-room has 19 of these 7 by 5 inch openings,

making an inlet for fresh air of over $4\frac{1}{2}$ square feet, distributed along the whole length of the wall of the opposite side of the room to the fireplace. The dining-room has fifteen of these openings, making an inlet of considerably over $3\frac{1}{2}$ square feet. Over the gasalier in the centre of the ceiling of each room is a perforated ornament, covering a 9 inch square opening into a zinc tube, 9 inches by $4\frac{1}{2}$ inches, making an outlet for the foul air of $40\frac{1}{2}$ square inches. This zinc tube goes along between the joists of the ceiling into a 9 inch by $4\frac{1}{2}$ inch flue in the brick-work of the wall, between the corridor and the room above, where it is regulated by a valve. This flue rises up inside the wall, and opens into the foul-air chamber formed underneath the roof of the corridor. The flues from the rooms, as well as those from the kitchen, hall, water-closets, and back staircase, open separately into this chamber.

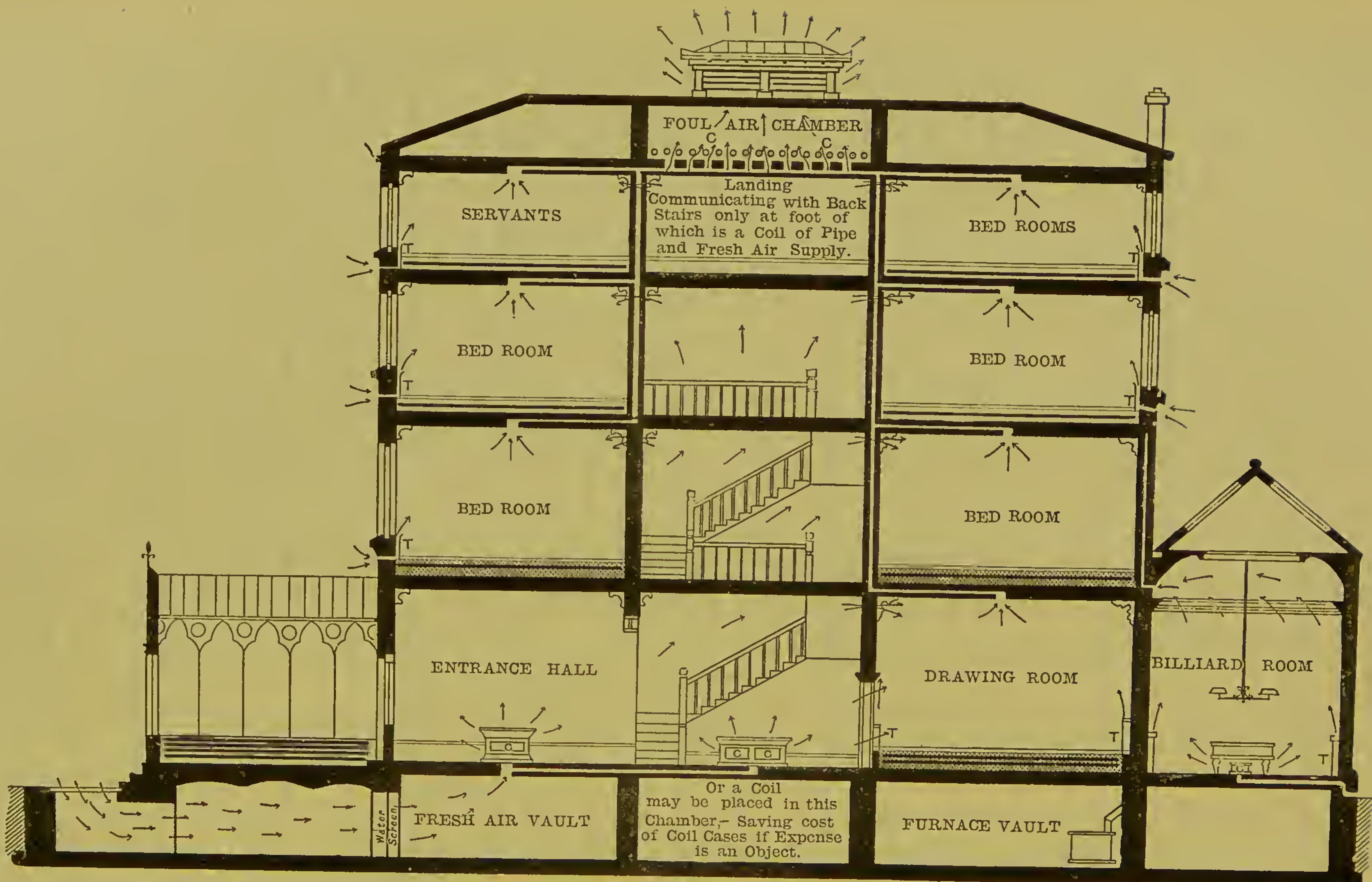
From this chamber a downcast-shaft (C) goes straight down to below the first floor, and rises up behind the kitchen fireplace (D), where it is flat, 6 feet by 1 foot; it is then collected into a somewhat square shaft (E), 32 inches by 26 inches. Up the centre of this shaft runs a circular earthenware smoke-flue from the kitchen fire, the outside diameter of which is $18\frac{1}{2}$ inches, leaving a foul-air shaft—the upcast—surrounding the smoke-flue; and these together form a large chimney-stack, which is carried up to a greater height than any other chimney of the house.

The warming and ventilation of a house by hot-water coils, and without any fireplaces, is shown in the annexed sketch (Fig. 238). It is the method suggested by Mr. R. Renton Gibbs, of Liverpool. The sketch explains the general arrangement. It is based similarly to the last plan, upon adopting the central hall or staircase for a reservoir of fresh warmed air from which the rooms obtain their supply. There is much to be said in favour of this plan in an ordinary house, provided care be taken to keep the central hall free from all impurities. It is sufficient to observe that the ventilation depends for its efficient action upon the extraction-shafts carried from each room to a foul-air chamber in the roof, in the floor of which hot-water pipes are placed. These cause an upward current, which carries the foul air away through a ventilating-turret. The fresh air which replaces the foul air is supplied either warmed, or else direct from the outer air, through vertical tubes in the outside walls. The warmed fresh air is brought from above the level of the ground through a screen, to free it from dust, to a chamber under the wall, whence it passes through coils of hot-water pipes into the halls and staircases, which form a reservoir of fresh warmed air. A perforated cornice below the ceiling of each room, and opening into the staircase, allows this air to pass from the staircase into the rooms. As an additional source of heat, a hot-water pipe is carried along the wall of each room.

Many other methods of warming and ventilating a house have been proposed, and notably one by Messrs. Boyle.

These specimens are mentioned as illustrations of various methods which have been proposed, not as methods to be blindly copied, because to each some objections may be urged.

Many of these systematised arrangements are based on heating the air of the house to a high temperature, whereas it is desirable if possible to keep the walls warm and the air cool. Moreover, these arrangements are liable to the inconvenience that at times the apparatus on which they depend may be



T. VERTICAL TUBES —— HOT WATER PIPES. C. COILS.

Fig. 238.

liable to be out of order. They have numerous flues, which, when new and in good order, work well; but the flues are not easily accessible, would be very difficult to clean, and after the lapse of years they may become clogged with dust, and fail to act. A cobweb in a flue has been found to prevent almost entirely the flow of air. On these grounds it is often desirable to keep each part of a house as self-dependent as possible for its ventilation and warming.

There is one condition which occurs in large houses for which provision is scarcely ever made—that is, for the case of large parties. Dining-rooms are filled with guests, with lights, and with servants, whilst no provision is made for change of air. The atmosphere becomes loaded with scent of flowers, the fumes of the viands, the impurities from the combustion of the lights, and the foul air from the breath. The guests lose their brightness, they feel dull, and next day they often have headache. Similarly at large evening parties, the lights, the numerous guests, all fill the air with an impure atmosphere which is most oppressive, and frequently most offensive; and at balls the effect of the exercise of dancing is to ensure the bad condition of the atmosphere. All this could easily be avoided, but it requires due provision to be made for ventilation. It may be fairly asked why should not the host feel himself equally bound to give his guests pure air as to give them brilliant flowers, bright lights, good cooking, and rare wines. Pure air would cost him little in comparison, but it is not seen, and therefore it has been little thought of. It should be regarded as an axiom that all rooms subject to be used for special receptions, such as rooms at hotels where public dinners or balls are held, large dining-rooms and reception-rooms in private houses, should be provided with means of ventilation proportioned to the number they are destined to hold. For this purpose, when the room is only occasionally subject to be occupied by large numbers, special modes of extraction or of forcing in air, to be applied during the reception or dinner, would probably be found to be most advisable, because the large amount of change of air necessary in a large assembly might be found unpleasant in a small one. In these days, when gas-engines will be soon a necessary adjunct to every house, fans to be worked by the gas-engine when required might be the easiest arrangement.

M. Joly, of Paris, has proposed to force air into dining-rooms at banquets and into crowded ball-rooms by means of a fan worked by hand, to relieve them from the fearful oppression which is produced on such occasions. He carries a perforated tube, which for temporary purposes may be of gutta-percha, round the cornice of the ball or banquet-room, and connects this by another tube with a fan to be worked by hand during the evening when the rooms are full. Thus a constant current of cool fresh air is forced into the room, and descends on to the occupants. It would, of course, be preferable to have the rooms as originally constructed provided with shafts to carry off the heated air, and inlets to admit fresh air. These should be proportioned to the full occupation of the room, but provided with valves to limit their operation to suit different numbers of occupants.

Mr. Verity, of London, proposes to propel air into rooms by means of a fan worked by water-power brought down from a cistern at the top of the house. The following is a description of the arrangements thus proposed.

The ventilator somewhat resembles in appearance an ordinary gas-meter, and occupies about the same space. A cistern is placed in the highest available position

in the building in which the apparatus is to be used, and a $\frac{3}{8}$-inch pipe conveys the water to the machine. The internal mechanism consists of a drum, with a set of fans, worked by a fly-wheel, placed in the centre and on the same axis as the fans. Two pin-hole jets of water directed on to the fly-wheel put these fans in rapid motion. The fans draw in the air from the outside, and propel it into the room through inlets provided for the purpose.

The water, after leaving the wheel, is discharged through small orifices in a shower across the inlet-tube so as to wash dust and soot out of the incoming air, and

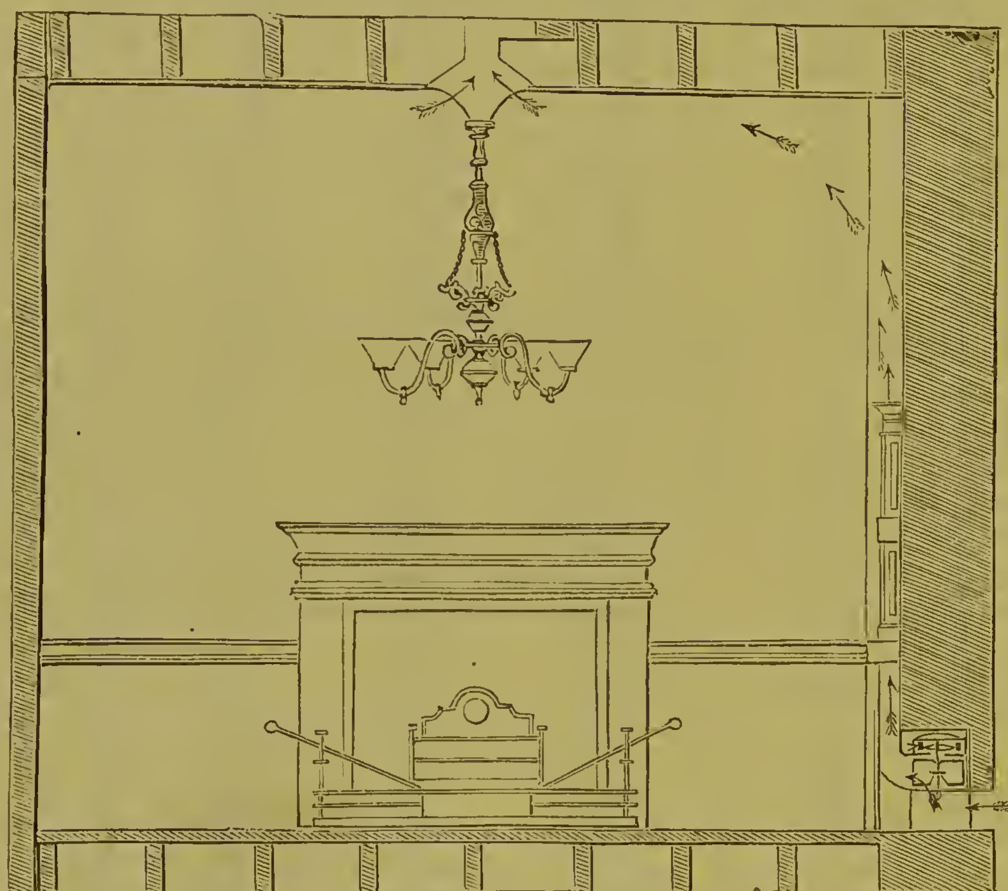


Fig. 239.

finally passes off by a pipe into a lower cistern. In the event of requiring a dry atmosphere through the apparatus, this can be had by turning a tap which causes the water from the wheel to pass off direct. A chamber is provided in the inlet-tube for ice to cool the air in summer, and a box can also be added for the introduction of fumes from scents or from disinfectants.

A velocity of current of from 15 to 20 feet per second, and even more, may, if desired, be obtained. The volume of the air passed through the machine varies according to the size of the fans, and may be regulated to any required degree by checking the flow of water against the fans, by turning the tap. The accompanying sketch (Fig. 239) shows the manner in which Mr. Verity applied these fans to a room. The vitiated air is drawn off from an opening in the ceiling connected with a shaft, at the top of which is placed some form of coil.

In cottages and artisans' dwellings it is very difficult to secure ventilation. Ventilating-openings in such rooms are almost certain at times to produce a feeling of cold or draught, and then to be closed. For living-rooms in cottages the fireplace always produces ventilation: but in the small cottage rooms it is very liable to produce draught. A fireplace for admitting warmed air was adopted for married soldiers' quarters in the British army which might be more generally applied to artisans' dwellings. This grate is shown in the annexed sketch (Fig. 240). These grates have been made for the War Department by Messrs. Benham, of Wigmore Street, London. They have a small oven, and an open fire; warmed air is introduced into the room by means of an iron flue carried up from the fire-brick lining of the stove inside the chimney, and introduced into the room near the ceiling through a louvred opening; by this means the heat of the smoke is utilised to warm the air admitted into the room. This description of grate was devised for the purpose of combining a power of cooking for a cottage with great compulsory economy of fuel.

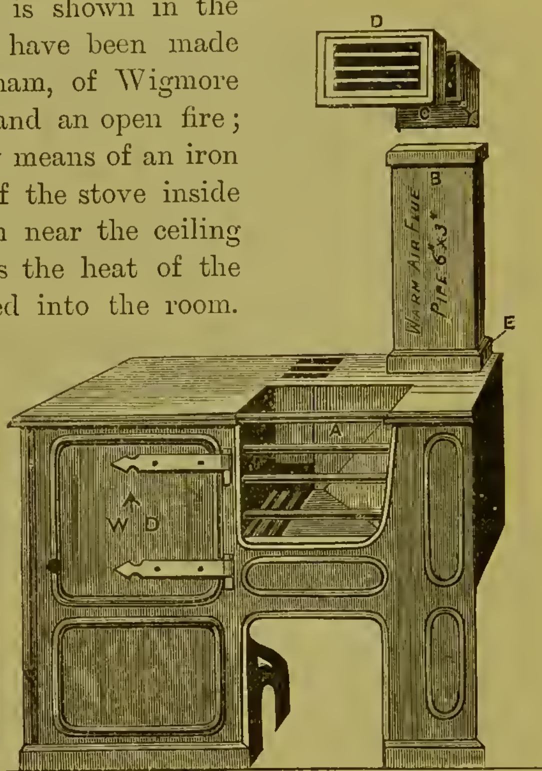


Fig. 240.

A, Fire-lump with warm-air flue through back; B, Warm-air pipe to fit into socket on hob, in lengths of 1ft. 3in. each; C, Bend to fit socket of the above pipe; D, Mouth-piece with louvre front to fit on bend. No. 1 of these 6 in. long supplied with each range. Increased heating-surface for the hot air is provided by means of a grating inside the socket at E.

For sleeping-rooms in cottages the safest plan is to make the room as near 10 feet high as possible, with sash-windows carried nearly up to the ceiling, and every room should have a fireplace; for although it may not be used often it will ensure some degree of ventilation.

In cottages, as in the dwellings of artisans in towns, it seems remarkable that gas is not more utilised than it is. It would almost seem as if at present the arrangements for heating and cooking by means of gas were in advance of the intelligence of the age. Gas is economical if carefully managed; but gas is decidedly expensive if it is kept lighted after the actual necessity for its use has ceased. It saves the trouble and dirt which coal entails; it is always to hand; it never wants looking to whilst it is performing its work; it can be extinguished when its work is done. In this lies its economy; but with a careless housewife, who leaves it burning after it has done its work, it will be found much more expensive than coal; therefore in large establishments it has been found wasteful. For cottages it ought to be very economical. Where the mistress does her own cooking and washing, &c., it would be eminently advantageous. At the present time apparatus designed to meet the waste of the small household are not so perfect as they should be.

CHAPTER LX.

OBSERVATIONS ON COMBINED SYSTEMS OF HEATING.

THERE ought to be considerable economy in a system of combined heating for small tenements. An arrangement which whilst economising fuel would prevent smoke, would be of enormous advantage as a means of preserving a greater purity of atmosphere than now prevails in large towns. But so long as coal is cheap, so long as people are allowed to vomit smoke from all their private chimneys, and so long as the chimney-sweep is allowed to push out all the soot into the air at a convenient level for polluting the air for breathing purposes, so long will any improvements in this respect be deferred.

The use of gas would no doubt remove these disadvantages, but it is noteworthy that in the United States a combined system has been put in operation, and this has been by means of steam. We have already shown that steam is especially applicable to heating-purposes under certain conditions; as, for instance, in large buildings, or where the heat has to be conveyed long distances. It has been applied for warming houses from central depôts on a large scale in the United States, upon a plan devised by Mr. Holly. The system is also in operation at Springfield, Mass.; Denver, Col.; Detroit, Mich.; Lynn, Mass.; Auburn, N. Y.; and other places. This system appears to have arisen from the advantages accruing to workmen, from having power supplied to them on a combined system. Thus it was found convenient for persons who had steam-engines to combine to obtain steam from one source of supply, and it followed that heat might be conveniently supplied on the line of the steam-pipes. The following is a brief account of the principal features of the arrangement :—

The steam is generated at a central boiler-house. Mr. Holly recommends the Murphy Smokeless Furnace, with regard to which he says :—"The perfect combustion and consequent total abolition of smoke from bituminous coal, and relative economy in the production of steam, are not the only points of superiority, as its cleanliness, ease of management, and saving of labour are almost equally important. The stoking of the boiler resolves itself merely into dumping the coal from cars into the bin above the firebox in front of the boiler, and occasionally pulling it towards the feed. A little engine carries it into the coking-chamber, dumps it at the proper time on the grate-bars, and by means of levers moving the shake-bars to and fro slowly, clears the bars of ashes. The doors are never opened, and one attendant, without a fireman's skill, will manage a battery of six boilers worked by the same power."

The steam is supplied from a central fire to a large number of houses for domestic purposes, and thus the necessity of having separate fires in each house is avoided. In 1880 there were 300 consumers in Lockport, and four miles of pipe. The system had then been in operation four years. The houses are heated from the central supply through about four miles of mains made of ordinary lap-welded wrought-iron steam-pipe, radiating from the boiler-house.

To prevent condensation the pipes are wound about, first with asbestos, followed by hair felting, porous paper, manilla paper, finally thin strips of wood laid on lengthwise, and the whole fastened together by a copper wire wound spirally over

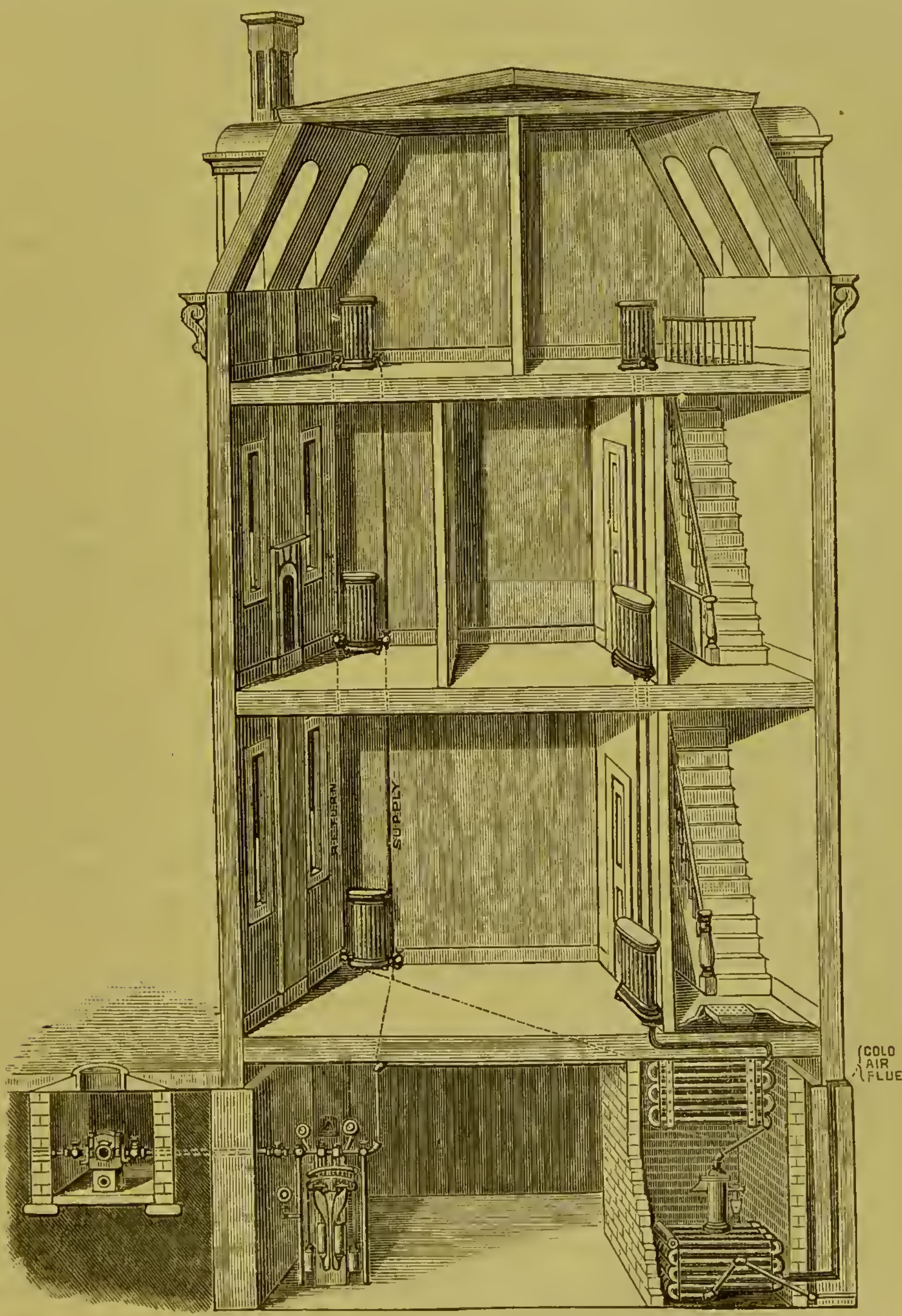


Fig. 241.—Steam Heating-system in America.

all. This is thrust into a wooden log, bored to leave an intervening air-chamber between the pipe and wood, and of sufficient size to leave from three to five inches of wood covering. The elasticity of the wrappings permits the free expansion and contraction of the pipe irrespective of the wood log, which is securely anchored

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and made immovable. The whole is placed in a trench a short distance below the surface without regard to frost. At the bottom of the trench is laid an earthen tile drain, to carry off any earth-moisture, and in order further to ensure the continuous dryness of the wood log enclosing the pipe, if desired, one-and-a-half-inch planks are fastened around the log, leaving an air-space, and the whole daubed with coal tar and covered with earth.

The largest mains in use at present are ten inches; they diminish, in proportion to the steam to be conveyed, to two inches.

Experiment and practice, verified in fifteen cities, show that the most economical pressure to be maintained in the mains is from 40 lb. to 60 lb., although in some cities 70 lb. has been used. Experience with large mains is yet limited, 10-inch being the largest in use. By calculation, the condensation at 60 lb. pressure is stated to be, in 3-inch pipes, per mile, 2·6; in 6-inch pipes, per mile, 2·0; in 12-inch pipes, per mile, 0·7. The condensation in large pipes is greater, but the relative percentage less.

The experience of Detroit demonstrates the fact that 60 lb. pressure could be maintained in four miles of 10-inch and 6-inch pipes, against the draughts for power and heat along the line. The capacity of a 6-inch pipe at 60 lb. pressure may be estimated thus:—A 6-inch pipe at 60 lb. pressure will discharge 102 cubic feet per second. A horse-power is one cubic foot of water, or 1·712 cubic feet of steam, or 427 cubic feet of steam per second. Therefore, a 6-inch pipe at 60 lb. pressure will supply 216 horse-power per mile, and the same amount of steam will supply 3,000 consumers per mile, averaging 12,000 cubic feet of air-space to be heated.

The expansion and contraction of metallic pipes between 32° and the heat of steam at 60 lb., say, 307°, is provided for by a junction and service-box. These are placed at convenient intervals along the line of 100 feet to 200 feet. The arriving-pipe from the boilers is inserted by a nickel-plated extension or telescopic joint, made steam-tight by passing through a stuffing-box. The departing-pipe is immovably attached to the box, so that one end of each 100 feet of pipe is fast and the other movable, affording free play to the expansion and contraction.

All service-pipes are taken from the junction-box, which is securely bolted to the masonry and anchored to the pipes. The bottom of the box being placed lower than the pipes, all water condensation is carried forward and deposited in it, to be taken up subsequently as entrained water, and re-converted into steam, at lower pressure, as the steam passes through the reduction-valve.

At each point of consumption there is a cut-off, under the control of the consumers.

The supply-pipes from the mains to the houses are 1½ inches in diameter, and within each house ¾ in. pipes are used.

In addition to the cut-off tap from the main, under the control of the consumer, there is a pressure-valve or regulator, by means of which the pressure of steam is reduced, and the supply to the building regulated automatically and with unerring precision. This is accomplished by two diaphragms of rubber packing, acted upon by weighted levers, and moving two slide-valves. The first valve is weighted to 10 lb., and the second to 5 lb. or 2 lb. if required.

After the steam has passed the valves of the regulators, it enters the meter

placed above the regulator at a uniform pressure. This meter resembles in its movements those of a 55-day American clock: as the steam passes, the movements are made to rotate a screw, upon which hangs a pointer moving along a dial; each revolution registers an arbitrary unit, the value of which has been previously ascertained by weighing the water. The clock marks the time and the register the quantity, both of which being always uniform at any given pressure, absolute accuracy may be obtained.

The distribution of heat in the apartments is by means of radiators (Fig. 241), consisting of inch pipes about thirty inches long, placed vertically, either in a circle or in a double row, and connected together top and bottom. Steam is admitted at the top in such quantity as desired, the bottom being open, the amount of radiating-surface being determined by the amount of steam; thus, a little steam will occupy the upper portion of the tubes, the lower portion being cool, the amount admitted being controlled by an inlet valve, so adjusted that the temperature of a room may be maintained at a low degree or raised to the full capacity of the radiator, and is easily controlled by a thermostat applied to each radiator, so arranged as to open and close the valves, admitting steam to the radiators: this valve may be set to operate within any ten degrees of temperature, so that the heat of a room may be automatically maintained at any point desired.

The advantage of this form of radiator is its economy and ease of graduating to all weather. A small portion may be made hot, while the remainder is cold. The steam and water of condensation give off all their heat, and there being no valve in the return-pipe, and no pressure, there is no cracking and sputtering noise as in pressure radiators. A quarter-inch pipe will supply steam for radiators for warming 6,000 cubic feet.

The condensed water from the radiators is conducted in protected pipes from all parts of the building where steam has been used back into the basement through the trap into coils of pipes set in a brick chamber; into this chamber cold air is admitted from the outside of the building as in an air-furnace, and, coming in contact with the coils of hot water, abstracts the remaining units of heat, and passes up through the registers into the rooms above as warm, pure air; while the water, now cold, passes into the well for future use, if required.

The trap is a simple device to permit the escape of the water of condensation, while retaining the steam. The trap is a vertical cylinder at the bottom of the return-pipe, in which is placed a bucket suspended by a lever connected with a valve which, when raised, opens the pipe leading from the bottom of the trap. This bucket is balanced when full of water, but when the overflow fills the outer vessel the bucket rises, opens the valve, and the water below escapes.

The laid-on steam may be used for certain cooking-purposes. Hot water for use may be had at any moment, day or night, by means of a novel apparatus like the sprinkler of a watering-pot, attached by a rubber tube to any radiator or pipe in the house, and, in an incredibly short time any quantity can be boiled without noise or slop; for example, a bucket of water can be heated in three minutes, and sufficient for a bath in ten minutes.

For baking and roasting, superheated steam is required, although both animal and vegetable food can be cooked at the temperature of boiling water; to brown meats, to broil beef steak, and form the crust of bread, requires a temperature of not

less than 300° to 420° degrees of heat, being an amount due to a steam-pressure of 60 lb. to 350 lb.

In Germany, bread is baked in ovens heated by steam at high pressure, and French cooks have long been in the habit of preparing their nicest broils of delicate game by high-pressure steam. It is stated that the Silsbee oven is arranged for super-heating the steam by means of gas, to make it applicable for purposes of baking, broiling, and roasting.

It is alleged that this stove is capable of performing all the duty of the best cooking-stoves in use, without inconvenience, with satisfactory results, and in a short time.

As in the case of gas-supply, the Steam Supply Company lay their pipes up to the houses, the consumer paying for all internal pipes, fittings, and radiators.

In a moderately-sized eight-roomed house, the expenses of these have been stated to amount to about 150 dollars, or a trifle over £30; and in a larger house, with more expensive fittings, 500 dollars, or about £100.

In the matter of the expense of this system, the facts at hand are not sufficient to show the economical results. The houses supplied have not been continuous, and consequently the length of main per house, and the loss for condensation per house, have been greater than would otherwise be necessary. In the absence of all previous experience as to the cost of manufacturing and distributing steam, the Company, when they commenced operations at Lockport, supplied heat at a price equal to the previous average cost of coal to each consumer, with satisfactory results to all concerned. As an example, the school-house measured 105,000 cubic feet of air-space to be heated. The average annual cost of fuel, labour, repairs, &c., had been $649.00; of this $300.00 was for the item of coal. The Company therefore agreed to maintain a temperature of seventy degrees from 8 o'clock a.m. to 6 o'clock p.m. for $300.00 a year, or £60; and the warming and ventilation of the building gave entire satisfaction to the trustees and the pupils. Experience, thus far, rather tends to diminish than increase the expense of steam heating. The Company have since reduced their charges for heating that school-house to $267.00 per annum, thus saving the city $382.00 per annum. The great advantage of the system appeared in the saving of annoyance in handling coal, ashes, kindling, &c.; also the expense of stoves and repairs; but further experiment led some steam companies to lump their charges for steam for 8s. per thousand cubic feet of air-space per annum, which was found to be a still greater economy; but upon the introduction of the meter made to register about that rate, a further saving has been effected by cutting off radiators in upper rooms, parlours, &c., when not in use, and paying only for the steam actually consumed. Its economy, when applied to cooking, may be estimated thus: a family will use 20 lb. of coal, together with the kindling necessary to make a fire, for cooking breakfast, and the coal is all lost; now 20 lb. of coal will convert 200 lb. of water into steam, which is enough to run from ten to twenty steam cooking-stoves one hour.

It may be further instanced that at Detroit a Steam Heating Company has been recently established which is being gradually extended. By accounts from Mr. Gordon Lloyd, the engineer of the company, it heated a variety of buildings, stores, offices, two banks, one publishing office, one boot and shoe

manufactory, &c., belonging to nineteen distinct owners, with an aggregate cubic capacity of 3,300,000 feet, in addition to which it furnishes power to eight distinct establishments varying from 2 to 65 horse-power—in the aggregate 196 horse-power.

The cost last year was about the same as that of private heating, but it would be less on an extended scale, provided the consumers be not too scattered, necessitating an undue proportion of street-main. It is not usually practicable in cities to return the water of condensation to the boilers, which generally is a great economy, and would be done in all private or isolated cases. Moreover, Mr. Lloyd considers that the combination of heating with the supply of steam-power is not advisable, because whilst the pressure required for the latter is at least 50 lb., for heating-purposes from 3 lb. to 5 lb. would suffice.

Occasionally one hears of the bursting of the steam-pipe in a street, which occasions much confusion from the continued volume of steam which pours out; but whatever may be its drawbacks, there can be no doubt that a system of steam heating on a large scale would greatly diminish the evils of smoke in the London atmosphere from which we suffer, and it would especially produce very great comfort in the dwellings of the working classes, and any increase of cooking could be supplemented by gas.

The system would appear to be one eminently adapted to be applied as an experiment in some of the new model buildings, such as those of the Artisans' and Labourers' Dwellings Company, or the Industrial Dwellings Society, or the Metropolitan Association for Improving the Dwellings of the Labouring Classes. In the buildings of these societies, of which all the tenants are under one management, the introduction of such a system would appear to be very economical, and to command the best chances of success.

CHAPTER LXI.

CONCLUSION.

It is impossible to lay down rules which should be applied in every case for either warming or ventilation; because the conditions are so different in every case. In these few examples we have endeavoured to illustrate what has been done by various persons, not as specimens to be blindly copied, but as furnishing ideas for the consideration of those who have similar work to do.

However well planned a system of warming may be, there is one general cause which leads to the complaint that it fails. The fact is, every one has different sensations of heat and cold. One man desires a temperature of 70°, another feels it too hot at 56°. The open fire has this advantage, that one man may warm himself at it and get as close to it as he likes, and another may keep away from its rays and yet be in the society of those who profit by its heat. In a room heated by stove-pipes or warmed air this is not so. All must undergo the advantage or disadvantage of a similar temperature. This alone makes the subject difficult. But there are, in addition, the difficulties arising from the shape and size of houses, from the conditions of site and exposure, and many other matters already attended to: for these reasons the subject of ventilation is complex. The use of giving examples is as much with the object of showing how improved results could be obtained, as of elucidating what has been done.

There is no single plan by which ventilation can be conveniently secured. What is good in one case may not be applicable in another; and it is only by carefully adapting general physical laws to the special requirements of each case that success can be obtained. The more simple the plan adopted, the greater will be the assurance that it will be ready to act efficiently at all times to ensure a change of air.

It will be obvious that the necessities of a mild or equable climate like England differ essentially from those of a climate subject to such extremes of heat and cold as the United States of America, or the continent of Europe, and that therefore very different conditions are required in each case.

It may also be assumed that when the ventilation is required to go on uninterruptedly day and night, very different conditions prevail from those which are required when rooms are used for a short time by large numbers of persons.

The object of ventilation is to approximate the hygienic conditions of our indoor life to those which prevail when we are surrounded with a free moving atmosphere on all sides.

The nearer we can render the air indoors similar in purity to that out of doors, the greater will be the degree of health which we shall secure.

This short and condensed account of the subject has been written mainly in the hope that by continually directing attention to the subject, the public, the builders of houses, and the architects, will become thoroughly imbued with the necessity of paying more attention to ventilation than has hitherto been the case, and will all co-operate to produce what has hitherto been a wonder almost unknown, viz., a really healthy house.

HOUSE-DRAINAGE.

By William Eassie, C.E., F.L.S., F.G.S., etc.

CHAPTER LXII.

DRAIN-PIPES, ETC., AND MODE OF LAYING.

Choice of Drain-pipes—Brick Drains not necessary—Jointing of Drain-pipes—Declination of Pipes—Cradled Drain-pipes—Pipes affording Means of Inspection—Bends and Junctions—Syphons—Drains should be Outside the House whenever possible—Drains of too large Sectional Area—Iron Drain-pipes—Drain-plans—Drain-cleansing Machinery—Waste-pipe Cleansing Contrivance—Service-cleanser.

Under the Section of Architecture, the sanitary equipments of the inside of a house which relate to drainage have been duly treated. For instance: the baths, lavatories, and sinks were duly noticed, and also much valuable information given regarding the various kinds of water-closet appliances for indoor use. The Section which I have been asked to supply will refer to the arrangements out of doors—taking up the drainage outside the walls of the house, and giving necessary information regarding the laying-down of drains, the choice of traps and gullies, the treatment of soil-pipes and outdoor closets, the disconnection of the house from the main drain or sewer, the choice of an outfall, and, at least, some of the varied and most useful methods of dealing with the water-borne sewage from a house or mansion in the country. The chapter upon Disconnection will also bear upon the treatment of houses the drainage of which finds its way into town or city sewers.

As far as the health of the inmates is concerned, the necessity for a sound system of drainage might be said to take first rank; for, however perfectly the house may be built, heated, lighted, and ventilated, except the underground drains be properly laid down the residence will never be free from occasional outbreaks of disease. The more ordinary faults which seem to have been committed in the draining of houses which have been already built will be treated by an able writer under another Section. I have to deal with the treatment of houses, building or still to be built, and to give the reader the most modern and soundest information upon the subject.

DRAIN-PIPES.

In regard to the choice of the drain-pipes to be used, a few words would not be supererogatory. Fortunately, there are a number of potteries within easy reach of each county where excellent glazed and socketed stoneware pipes can be obtained. Some of them excel in the goods they manufacture, and produce pipes with which no fault can reasonably be found; but others are less renowned in this respect, and produce rather inferior goods. For example: the interiors are not smooth; the ends of the pipes do not fit the sockets anything like accurately, and have awkward

spaces, making it difficult to lute them properly; others, again, are either fired too little or over-fired in the kiln; too brittle, or of insufficient thickness to resist fracture when even an ordinary load is passing over them, and when, owing to the only possible gradients, the pipes cannot be laid in a deep trench. The proper plan to adopt is, therefore, to inspect the pipes as they are unloaded from the railway trucks, and there and then to reject all pipes with distorted sockets or ends, and all those that do not ring soundly, or are in any way chipped where the joints have to be made. And when the pipes are ordered from the manufacturers, they should be informed that a rigid inspection will be insisted on, and all objectionable ware returned on their hands.

I am not aware of any circumstances which could arise in connection with house-drainage where it would become necessary to lay down brick drains, or even drains built up of stoneware segments, because whole pipes are manufactured in various parts of England and Scotland, &c., ranging up to three feet and upwards in diameter, and formed either round or egg-shaped in section. It may, therefore, be taken for granted that the householder requires to deal with stoneware pipes only, in and around his dwelling; and throughout the following pages pipe drains of this description will alone be taken into consideration.

It is of the utmost importance that the drain-pipes which are to be laid inside the dwelling should be of the best possible pattern, as regards the method of jointing. There are many different kinds of drain-pipe joints extant, and patents are being continually taken out to meet the requirements of architects and engineers in this direction. An excellent and well-known sanitary drain-pipe, with an improved and very satisfactory joint, is that known as Stanford's, sold at Lambeth, shown at Fig. 242.

Here a tight joint is obtained by casting upon the spigot A and socket B of each pipe, by means of moulds purposely prepared, rings of cheap and durable material, which fit mechanically into each other when put together, and are almost as perfect as though each pipe had been turned in a lathe; the section of the ring being, however, such as to afford a certain amount of movement without destroying the proper fit of the joint.

Fig. 242.

In laying these pipes, the spigot and socket form a complete joint, if even merely smeared over with some grease. It is, nevertheless, wisest to enclose the joint with a luting of cement as well.

This kind of pipe, or some equally good improved joint, should always be adopted, whenever possible, for the inside drain of a house. This is not saying that picked ordinary glazed and socketed pipes will not serve for indoor drain purposes, but merely that better joints can be ensured by making use of the best appliances of modern date. The value of such an improved joint, as shown at Fig. 242, is that the pipe is rendered trustworthy, independent of any cement luting; that the joint can be inspected before being put in the work; that no luting material can possibly obstruct the inside of the pipes; that subsoil-water is absolutely excluded; and that no sewage-matter can escape from the pipes, to poison wells or rain-water tanks.

It is in no way necessary, in such a work as this, to enter into any detail as regards the amount of declination, or fall, to be given to the pipes when being

laid, because it would, in most cases, be misleading; and, as a matter of fact, nearly every house requires different treatment in this respect. It would be the province and duty of the architect or engineer to decide as to the amount of inclination and the velocity in feet per second which each case requires or admits of.

When the trenches in which the pipes are to be laid have been duly dug out, care should be taken to see that the levels chosen are accurate throughout, and a hard bed secured for the pipes to lie upon. Where any indication of soft ground or running sand shows itself, concrete should be laid down, so as to afford a proper rest for the pipes. The drain-pipes should then be laid, working on towards the house, and carefully jointing each pipe with the best cement, making sure that the lower portion of the joint as well as the upper is carefully filled with the luting-material. There is no necessity for caulking the joints with any fibrous material, but making them with cement only. As each pipe is laid down, special care ought to be taken to see that where cement joints are used this material is carefully wiped away, should it protrude in the interior of the pipe as the joints are being pressed together. A neglect of this precaution will entail much subsequent trouble and annoyance, inasmuch as the proper flow of the sewage in the pipe will be interrupted, and obstructions formed, where the bad jointing has been allowed to pass. It is here where Stanford's and other improved joints are of value.

It is held by some authorities that in order to obtain a drain with perfectly staunch joints on the march of the drain, it is necessary to make use of cradles of glazed earthenware, upon which both pipe and socket can rest. This was first introduced into practice by the late Mr. George Jennings, of Lambeth. Certainly, this is an additional precaution, as it enables the joints to be got at all round, and the pipes are kept steady in their place. Some of these cradles are made so as to utilise the ordinary pipes, but whether they be used or no, care must be taken, as before mentioned, to secure a sound bed for them to rest upon. A sketch of a patent joint of this description, known as Maguire's, and much used in Ireland, is given at Fig. 243, as an example of these cradles. This pattern of pipe and cradle permits of an independent cement joint to be made on the lower half of the socket, where the sewage runs, by pouring in liquid cement round the first joint after it has become properly set. The chief value of cradling the pipes is that it renders the pipes more to be relied upon, and prevents the workmen from having recourse to the use of wooden wedges under the pipes, which wedges are certain to rot away after a time where the subsoil is damp. There is no absolute necessity of going to the expense of this drain when laying down drain-pipes outside the house, provided the ordinary drain-pipes are carefully and properly laid.

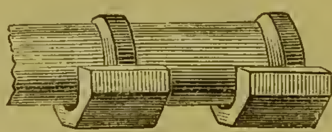

Fig. 243.

Sufficient has been said regarding the necessity of a sound and firm bed for the pipes to rest upon; but it may be taken for granted that the drains which pass through the inside of the house should be laid throughout upon a concrete bed, and after the joints have firmly set they should be covered over with two or three inches of concrete; for a cement joint, however well made, with an ordinary pipe, is liable to fracture, and may become insecure from other causes, such as expansion and contraction, &c. Where the extra precaution is taken of placing the drain-pipe in a concentric ring of concrete, it is advisable to pro-

vide, here and there, inspection-apertures in the drain, so as to be able to find out the whereabouts of and remove any obstruction which may have got into the drain.

Every pipe-manufacturer has his own system of providing inspection-caps of this kind, some merely cutting out an oval space on the top of a pipe and fitting there a lid with a flange; others dividing the pipe into two equal longitudinal halves; while others—as, for instance, Doulton—merely take a segment of the whole length of the pipe, treating it as shown at Fig. 244.

Some builders who do not know better are so enamoured of this kind of drain, that I have known them to lay the whole drainage of a house throughout with these patent pipes. But their only use is to provide, as stated before, a means for searching the drain with rods, or other contrivances, when a stoppage has been diagnosed. They are chiefly valuable in long passages; and where used, the covers should be bedded down with mortar or putty merely, a chamber formed for them, and a man-hole cover provided as well. Places for inspecting the drains in the inside of a house are always provided where there is a considerable length of drain; and the majority of architects and engineers now simply lay down a half-round pipe, two feet long, between the other drain-pipes at desirable places, raise the sides up in cement, and cover the space over with an air-tight iron man-hole.

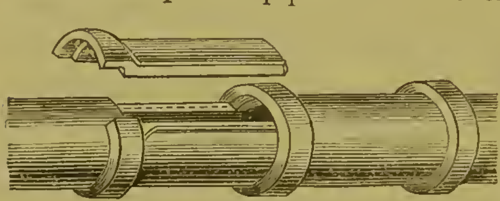

Fig. 244.

Where there is much traffic across the inspection-chamber, an iron man-hole cover is apt to become loose, and in such cases it would be preferable to bed down a stone over it, with a ring countersunk into it for the convenience of lifting. Such a stone should not, however, be bedded in cement, but rather in mortar, with merely an eighth of an inch cement jointing near the surface; and if this be done, the stone will come up easily, and without breaking it.

BENDS, JUNCTIONS, ETC.

There is nothing more essential in good house-drainage than providing proper bends. Wherever requisite, a very slight curve might be made with straight pipes, but it is a dangerous practice, and fortunately, there are easy bends now manufactured to suit almost every possible contingency. Several of these bends are shown at Fig. 245; for instance, a quarter-bend at A, one of the easier bends at B, and another form of easy S-shaped bend at C—all of them very useful forms. The best practice, however, is sometimes to form the bends with half-round pipes of the proper curves sought for, build up the sides, and cover it with an iron man-hole or stone and ring.

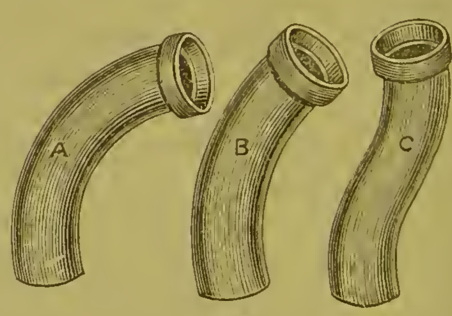

Fig. 245.

It is also of the utmost importance to provide proper junctions where junctions are necessary. They should, as much as possible, take the form of A, Fig. 246: that is, the junctioning pipe should be like the one arm of a V, and never be

at right angles with the main pipe—a mistake which is very frequently made by inexperienced workmen. Of course, both single and double Y junctions can be got at every manufacturer's. Undoubtedly, the best method of dealing with a junction is to make use of "inspection junctions." The goods affording access in this way are specialities, and have been constructed on the best forms, after a very long and gathered experience.

It is unfortunately too common a practice with workmen to endeavour to make a joint between large and smaller-sized pipes, without having recourse to proper diminishing pipes, such as shown at B, Fig. 246.

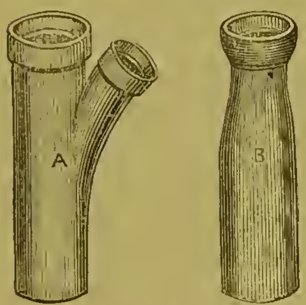

Fig. 246.

They diaphragm them off with a slate or with bricks, or they simply fill up with cement, and even with clay, the difference in section at the top. It would be better to wait a month, and pay an excessive price for carriage, than allow such procedure as this. At such places rats find an easy entry into the drains, and moreover, the cement cracks, the clay pulverises, and the *débris* falls into the pipe, and lays the foundation for a complete choking up of the drain.

SYPHONS AND DRAIN-LAYING.

The most abused article in a line of drainage is the syphon, and they are inserted in all sorts of improper places. Now, if there be anything about which one ought to be more careful than another in dealing with sewerage, it is the syphon. Sometimes they are improperly placed in the front of a sink, with a view of preventing the air of the house-drain from rising in the sink waste-pipe; sometimes at some little distance from the scullery grease-trap; sometimes at the feet of soil-pipes and of bath-wastes, where the latter join the main drain, sewer, or sewage-tank.

Wherever a syphon is positively needed, the plain syphon shown at A, Fig. 247, should be avoided in every case; and so also should all syphons where an inlet is placed in the middle of the dip, as shown at B.

Perpendicular drains are sometimes made to enter syphons, as, for instance, at B; but it is unwise to treat a syphon in this way, as for the most part these entries into the syphon were intended for inspection-purposes, and for the removal of any sand or other material which may have lodged in it. When inspection is wanted in a syphon, the entry is preferably made where shown by the dotted line at C, and syphons of this handy description are now becoming common.

It is wise, when laying down a syphon, to provide a pipe next to it which is provided with a raking-piece, for the introduction of the hand or cleansing-rods; such a pipe is shown at D, Fig. 247. Syphons, however, are now in the market which are not only provided with the cleansing-entry C, but also with the raking-piece attached to the syphon, as shown by the dotted lines at E. Syphons of this sort are always used in disconnection-chambers, as we shall see

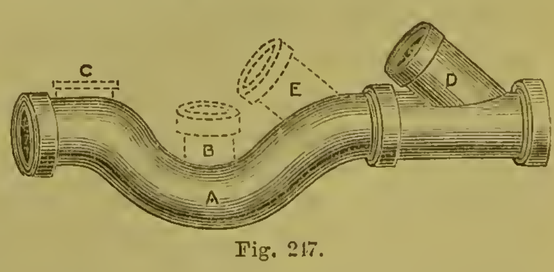

Fig. 247.

further on, and should be preferred to all others, placing them, of course, in a chamber with a man-hole over them.

Ordinary syphons, where the outgo is level with the income, are now rejected as a rule, and those special syphons chosen where the water or sewage obtains a drop of two inches or so in falling from one end of the syphon to the other. This fall in the syphon is very advantageous, and generally effects a clearage of the sewage to beyond the syphon, and on to the outfall. The common syphon does not readily clear itself, as it is ruled by mere gravitation.

Whenever possible, drains should never be laid inside the house; and this is one of the most salutary rules in house-drainage. It is a rule, however, often transgressed. If the majority of detached and semi-detached villas were examined, it is far from unlikely that the drains would be found passing through the centre of the house, simply because that treatment of the drain required fewer pipes, or because it was in a line with the scullery-sink or servants' closet, or because the butler's and housekeeper's room sink, by taking the drain in that fashion, would simply require to drop into the pipe. The leading of drains through the house is unavoidable perhaps in crescents and rows where the houses join together, but even then it is sometimes possible to avoid much of the evil by draining from both front and back of the house. It is a safe rule, at all events, not to allow any portion of the drain to enter a house if it can be avoided; and even when it can be avoided, and when the drain does not require to pass through the house, it is well to stop the pipe short of the exterior wall, and to lead any soil-pipe to it by taking the soil-pipe through the wall—when such soil-pipe must perforce descend inside the house—and to junction the metal with the stoneware pipe outside the house.

When earthenware pipes must pass through the walls, a relieving arch should always be turned over them the whole thickness of the wall. When this precaution has not been taken, and when a settlement takes place, the pipes are liable to be broken, and the drain will consequently leak at a dangerous place, inasmuch as the sewage will saturate the subsoil inside the house.

Drains are very frequently laid down of far too large a sectional area: six inches in diameter where four inches would have sufficed, nine inches where six inches would have been sufficient, and twelve inches where nine inches would have been ample. This laying down of too large pipes is one of the most besetting sins in house-drainage, when that has been left entirely in the hands of the builder. I have taken up twelve-inch pipes in a house, and replaced them with six-inch pipes. The sizes of the pipes to be used should not be decided haphazard, but advice taken upon this subject from a competent person. As a general rule, a four-inch pipe is sufficient for a cottage, and a six-inch pipe for an extensive dwelling. In deciding the diameter of the drain-pipes, due provision must be made for the rainfall, or serious floodings may be the result after every storm of unusual severity.

Where drains are laid in the vicinity of trees and shrubs, it is of the utmost importance to provide such a system of jointing as will prevent the roots from entering the interior of the pipes, and in due time filling the drain up, as they will invariably do. Merely well-made cement joints will not suffice, and clay-made joints are, of course, utterly out of the question in house drain-pipe laying. The best procedure to prevent the invasion of the joints is to coat well the joints, after being laid and cemented, with two or three layers of coal tar mixed with saw

dust, throwing concrete around them afterwards, and then again paying over the whole with another coat or two of the same material. Roots will invariably turn aside from such a neighbourhood as this.

There are several general rules connected with the subject of drainage which might be borne in mind, and I may mention a few of them. For instance, a drain should, if possible, have a little extra fall whenever a bend or a junction occurs in its line of march; a very little will suffice to counteract the effects of friction. Again, a large pipe should never deliver into a small one, or, where it can be avoided with advantage, a pipe into the same size pipe as itself. Again, it will sometimes prove useful, when a pipe may possibly be required to enter the drain at a future time near a specified spot, to provide a dummy junction, so as to avoid the disturbance of the main drain afterwards; such a junction, however, should be carefully stopped off by the earthenware disc provided for that purpose.

It is most unadvisable to lay down drains just after the foundations have been put in or the walls partly built, as no drains thus laid, although surrounded by concrete, can be said to be proof against the many mishaps consequent upon building. It is quite time enough to lay the drains in and around the house when the building is roofed in, and the heavy carpentering work completed. This is of more importance than is generally considered. Unfortunately with buildings built for sale, speculative fashion, the rule has been, and probably is, to lay the drains in immediately the foundations have been put in, this work being done by common labourers, instead of by skilled drain-men. The safe rule for the householder is, when entering upon residence in a house purchased from a builder, and not erected by his own architect, to have the whole of the drains overhauled, and the chances are that the whole of the drains will have to be re-laid. Builders are not yet generally made aware that house-drainage has nearly risen to the rank of a profession.

SUBSOIL-DRAINAGE.

It sometimes happens that the main drains from a house have to pass through land with a wet subsoil or places surrounded by springs, causing the water to run alongside the drains, and sometimes excavate hollows underneath the pipes, to the evident danger of their falling in. When such a state of things is revealed, it is customary to lay alongside the pipes one or more ordinary lengths of the common agricultural pipes used in field-draining, with simple butt joints, in order to take away freely the subsoil-water, this water being led to a separate outfall.

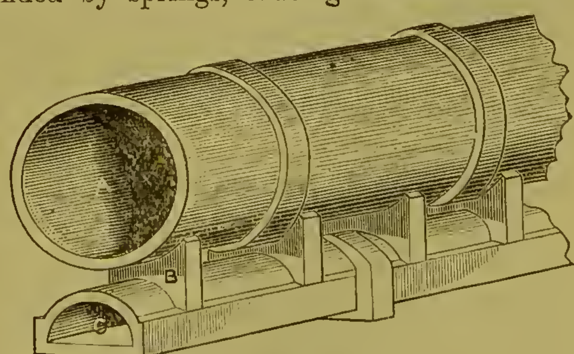

Fig. 248.

To provide for contingencies of this kind, Messrs. Brook, of Huddersfield, manufacture a pipe drain, supported by a loose retort-shaped pipe, with open joints below, and it has been frequently used with great success. This combined pipe is shown at Fig. 248: A being the pipe conveying the sewage, B the loose rest, and C the open-jointed—or rather, non-luted—subsoil-water conduit. If the last-men-

tioned be luted, it is only loosely protected by clay, so as to prevent a large ingress of earth or sand. The water above the level of the retort-shaped pipe is, of course, kept shut out from the sewage; but at a suitable change of level it can be turned into the upper pipe A, and used for flushing the subsequent lengths of drain. These pipes are only made of large diameter, and for ordinary purposes the use of ordinary field draining-pipes alongside the drain is to be commended.

Where a house is built upon ground which secretes water, such as loose gravel, moist sands, and the like, experience has proved that the house cannot be made healthy except the space which it covers has been drained by agricultural pipes of this description, and the subsoil-water removed to a suitable outfall. If the outfall be into the house-drain, which removes excreta and other foul wastes, then the collected subsoil-water must first of all deliver into open gullies before it is taken into the main drain. And in all cases where drains are taken from open areas and blind areas, as they are called, the same precaution should be invariably taken.

IRON DRAIN-PIPES.

Up to the present time I have been dealing with earthenware pipes only; but I should add that it is sometimes the practice with engineers to drain the house by means of cast-iron pipes. Such a system is commendable in many respects, as the joints are less frequent, the pipes more rigid, and if treated against the chance of oxidation, inside and outside, by means of the Barff or some other process, the drain will repay the extra cost. In Paris, iron pipes are always used inside the houses, and are generally placed above ground throughout their lengths, although this is mostly done because the pipes are obliged to be made so as to deliver into "separators," where the solids are mostly caught, and the liquids allowed to pass into what serve as main sewers in that city. At the present moment I am just completing the drainage of a large house in London where the whole of the drainage runs above the basement-level in galvanised iron pipes, fastened along the wall at a suitable gradient, everything delivering into these drain-pipes—except solely the soil-pipes—first of all in the open air.

Although this may by-and-by be a common practice, it must, however, be conceded that for all practical purposes a well-laid and concrete-protected underground drain is sufficient for the best purposes.

DRAIN-PLANS AND DRAIN-CLEANSING.

It is of the utmost importance to the occupier of a house that he should be furnished with an accurate drain-plan to a suitable scale, with an index, showing the descent of each pipe, and the position of every gully and other trap. I have frequently been obliged to examine houses which have just been completed, and found the builder unprovided with a chart of the drains which he had laid down only a few months previously. In one case the foreman had died, and he alone knew the direction in which the various pipes were laid. Drain-plans should even be made in triplicate: one hung up in the basement, for the use of the servants; another handed to the client, for placing in his cabinet; and the third retained by the architect and engineer, for future reference.

Very frequently, and from many causes, drains become choked, necessitating a

search for the obstructions, and a means either of finding out the exact place of stoppage, with a view of opening up the drain at that spot, or of by some means loosening the sewage-retarding material, and of pushing it onward to the outfall. Most drain-men provide themselves with drain-cleansing machinery, and, in my opinion, no country house should be without a complete set. A sketch of a complete set of this machinery is given at Fig. 249 : A representing a bundle of canes, with joints which easily screw together, and reaching in extent from thirty to a hundred feet when attached together. The rake for fitting upon the end of the first cane, and used for loosening and raking out any hard substances, is shown at B; the ball for pushing on solids at C; the roller, with brush for cleansing the inside of the drain, at D; and the double screw, for laying hold of bulky foreign substances, at E. This machinery can also be used for sweeping chimneys at a small additional cost.

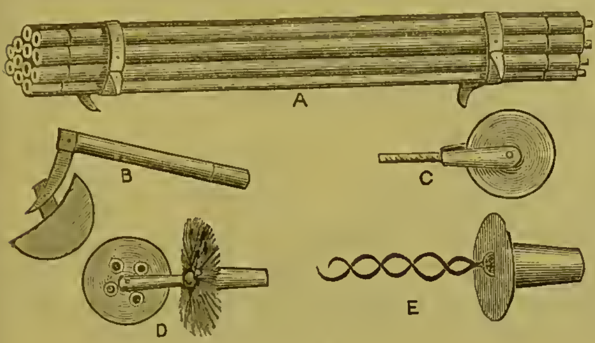

Fig. 249.

Another most useful contrivance to be kept in houses, ready for instant use, is the apparatus sketched at Fig. 250, which is most valuable for instantly cleansing the discharge-pipes of sinks and lavatories, and even closets, when they become partially or entirely stopped up. It is composed of an india-rubber cup, A, an iron disc, C, and a wooden handle, B. In using this force-cup, allow water to flow into the sink, basin, or bath, to a depth of about three inches, then place the india-rubber cup over the vent, and force the handle up and down several times with a quick motion; by this means the water beneath the cup is forced into the discharge-pipe, and the impulses produced by the manipulation of the handle dislodges the obstruction, and forces it through the pipe to the disconnecting-gully.

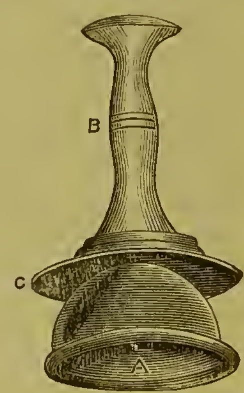

Fig. 250.

The last contrivance which I need mention is what is called a service-cleanser, and is very effective when any stoppage occurs in long lengths of waste-pipes and water service-pipes, which have been necessarily laid underground. This contrivance is shown at Fig. 251, and its action is as under:—The plug B is unscrewed, and about a gallon of water put in, whereupon the plug is replaced in the tightest manner; the vessel A is then charged with air with successive strokes of the piston, the flexible tube being attached to the pipe which requires cleaning by means of suitable connections. All that is then required is to turn the cock C full on, and the obstruction will be quickly driven out.

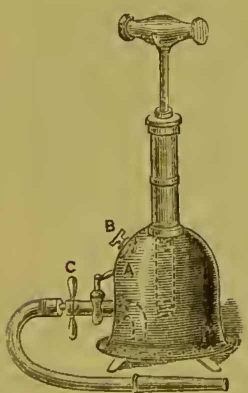

Fig. 251.

If the above general instructions are carefully attended to, the residence will be rendered healthy in every respect, as far as regards its underground drainage.

CHAPTER LXIII.

GULLIES AND OTHER TRAPS.

Area and Yard Gullies with and without Side Inlets—Importance of trapping Waste-pipes entering Gullies—Proper Grating Covers for Gullies—Bell-traps condemned—Best Traps for Floor-traps inside the House—Collecting Outdoor Gullies—Gullies collecting Solids—Garden and Road Gullies—Grease-intercepting Chambers and Traps—The Occasional Necessity for them, and Examples of the Various Kinds, &c. &c.

In regard to the drainage of houses and their private surroundings, a gully may be taken as representing a syphon trap, where the space below the dip or trapping-piece is much deepened, in order to intercept anything which may be undesirable from entering the drain. There are many patterns of these gullies, as every pottery catalogue will show, and some care should be exercised in the choice of a right one for the purposes required. For instance, it would be most undesirable, in a front or back area of a house, to allow the gully to contain such an immense quantity of water and silt as is always provided for in a street, because there is no necessity for providing against street and storm washings; and the only object is to provide the trap with an hydraulic seal, with some little added allowance of depth for the collection of sand and the solid wastes which may come from the sinks.

AREA AND YARD GULLIES.

For ordinary area and yard purposes, the simple syphon form of gully, slightly deepened, is the best: for instance, such a gully as is shown in section in Fig. 252, which may be said to be perfect for general purposes, the amount of trapping-water, A, and the silt-accommodation, B, being quite sufficient. When the silt-accommodation, B, is too deep, foul emanations are given off, bubbling up through the water, A, and pervading the atmosphere around the house. This kind of syphon is made with its outlet terminating at C, so as to join a drain raking up towards it; or the outlet can be made with a perpendicular fall, as shown by the thin line D, which line can be elongated by uprightly-set socketed drain-pipes, leading to a main drain below.

Until lately, yard-gullies were made without any side openings over the trapping-water and under the ventilated gratings, so that it was rendered difficult to lead anything into the gully, except what fell perpendicularly through the grating; but gullies are now constructed with flanged side entries, shown at Fig. 252 by the dotted lines E and F. Of course, the diameter of all the outlets can be varied to suit every contingency. Before side inlets were provided into yard-gullies, and when it became necessary to lead over the trapping-water the wastes of sinks, baths, &c., either a hole had to be chiselled in the stoneware, at the risk of breaking about ten per cent. of the gullies, or the waste-pipes had to be led over the edge of the gully, and between the edge of the gully and the cover to the gully, which is always separate, and which is shown at G—the space between being filled up with brickwork and cement. I only mention this lest, from want of stock at the manufacturer's,

from want of time to wait for a special pattern, or from remoteness from places where they are sold, gullies with side inlets cannot be obtained.

In purchasing yard-gullies, side inlets should always be chosen—and there are many patterns by different makers—because they are useful for disconnecting the wastes of sinks, or lavatories, or rain-water pipes, which would be made to enter the side inlets E and F. As for sinks, baths, lavatories, &c., which are fixtures inside the house, enough has been said under the head of "Architecture" to guide any one, but it is my duty to point out here that there are several necessary matters appertaining to the entrance of these wastes into a gully which it is well to know. For instance, it is not sufficient to say that the waste of any sink is properly disconnected simply because the waste-pipe has been led to deliver over the gully trapping-water; for if a trap be not fixed under the sink—preferably one giving means of access—the cold air will rush up the sink-pipe into the warm room, and also any effluvium caused by the decomposition of the water and sediment in the trap, which will be especially felt during the summer, when the sun's rays are beating upon the surface of the trap. I have known almost the whole of the drainage of a house condemned for the simple want of a trap under the butler's, still-room maid's, and housekeeper's sinks in a basement; the builder was sent for, and he considered the sinks properly disconnected, while at the same time they were not so, owing to the want of an access-trap. There is another precaution to be taken, and that is in some cases, even when the waste-pipe enters a gully over the hydraulic seal of the gully, to have the waste-pipe open both at the top and at the bottom. For example: if there be a lavatory on the ground or first floor, and the lavatory be simply trapped at the head of the waste-pipe, and with no ventilating continuation to it, there will be, sooner or later, a foul smell given off at the basin, due to the accumulation of the decomposing fats of the soap, which is apt to become fixed as a slime in the interior of the waste-pipe. This can only be cured by ventilating the waste-pipe above the entry from the lavatory basin. And this precaution is very necessary in the case of a bath-waste delivery.

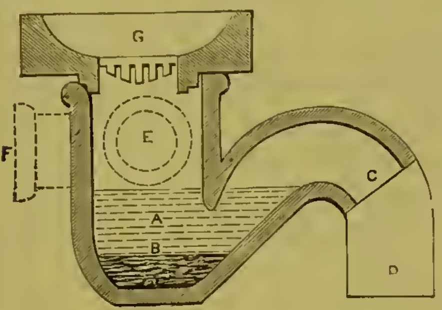

Fig. 252.

There is a matter of smaller moment, certainly, but one which, if not provided for, causes a serious discomfort afterwards: I allude to the kinds of gratings with which these yard and area gullies are covered. I consider the stoneware square or round cover, pierced with small holes, to be the very worst kind of gully-cover; and it is a matter of wonder to me why they are ever made, as nothing could be paltrier in appearance and more certain to fracture. Next to these, I would condemn the small, thin, cast-iron grating, which fits, whether loosely or tightly, at the top of the shallow socket of the gully; for this kind of grating is just as liable to break as the other, being level, or almost so, with the paving of the yard. The correct description of gully-cover is shown at G in the woodcut, Fig. 252, which consists of a Doulton's dished stoneware, ample-margined, with correspondingly thick covering, and with an easily-movable iron grating just over the gully-water. The edges of such a trapped cover form an excellent surface for the pavement material to finish against, and they also give a cleanly appearance to the yards in which they are placed.

Sometimes yard and area gullies need no side entrances, being merely fixed to remove the surface-water, which falls upon the pavement towards them. In such a case, use a small-sized gully of the same pattern as Fig. 252, unprovided with side inlets; using, however, the dished cover.

A most reprehensible pattern of yard-trap for the removal of surface-water is that known as the bell-trap, shown in section at Fig. 253. Wherever this trap is used, it sooner or later becomes the curse of the household. Very little water can pass through it; there is an insufficiency of trapping-water, the movable cup-bottomed grating not dipping sufficiently deep. The upright pipe also retards the flow of water, the annular space A becomes filled with sand and sooty washings, the trapping-water gradually disappears, and finally, no trapping-water is left at all. The cover B also breaks across, and the cup fixed below it breaks off, leaving no guard whatsoever against the foul gases, and hence the air in the neighbourhood of the trap is loaded with them.

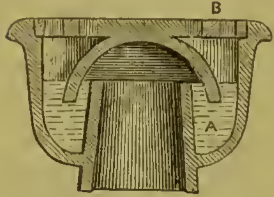

Fig. 253.

These bell-traps are most dangerous when fixed inside a house, where they are frequently placed in the floors: such as, for instance, in the laundry, in the meat-larder, and in the dairy, in order to provide for a delivery on to the drain of the water used in scrubbing out and swilling the floors. Traps at these places are, however, most necessary, especially in large establishments; but the trap should take the form of one which cannot be untrapped by the lifting out of the cover. There are many traps very suitable for this purpose, and almost any lip-trap would answer. What is known as an Antill's trap (see Fig. 254, where a section is given) can be advantageously used when it is sufficiently large for its purpose, and when the hand can be got up behind the dipping flange, C, in order to keep the trapping edges clean. Even if the cover, B, of this trap were lifted, the flange, C, does not rise with it; hence the trapping-water, A, remains. This trap, however, would be objectionable, despite its certain advantages, if it were used in outdoor areas; but for indoor use, in floors of dairies and the like places, which floors are washed out by buckets of water being thrown over them, it will do admirable service. One thing, however, must be most carefully attended to, and that is, to see that the drain from these house interior traps, or small gullies, deliver in disconnected fashion over the trapping-water of a gully outside the house, such as that shown at Fig. 252. When this has been done, and not otherwise, should a trap be placed in the floor—in other words, the indoor floor-trap should be disconnected to an outdoor ventilated trap before it enters the main drain.

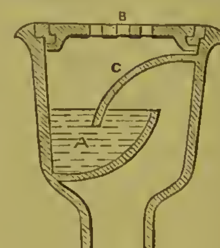

Fig. 254.

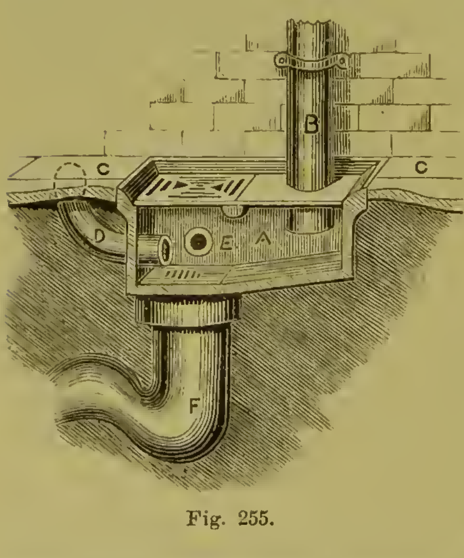

Fig. 255.

Sometimes a stoneware trap for yards and areas—and outdoor traps should always be of stoneware, because they never rust, and the glaze inside renders them

cleanly—is required of a more compact order than the gully shown at Fig. 252, to accommodate more sink deliveries, for instance, and also to take within itself the rain-water descending a rain-water pipe from the roof or flats, as also the surface-water from the yard or area. A compact trap of this description is given partly in section at Fig. 255, and is known as Bellman's Gully, made in London. The body of this trap is shown at A, sink entrances into it as at D and E, rain-water pipe entrances as at B, and surface-water drainage from the pavement C, C; all these deliveries passing through iron gratings into a syphon trap below, marked F. This trap is largely used in London.

There are numberless traps used for the above purposes which it would be needless to describe, and therefore I only give descriptions of the more specific kinds.

SOLIDS-COLLECTING GULLIES.

Traps are sometimes required in yards which possess a facility for lifting out any silt or sand which has been used for scouring purposes and the like. In order to effect this, a silt-box is provided, which can be lifted out and emptied, without making use of the hand or of any utensil for scooping out the bottom of the gully. A trap of this kind (Dean's) is drawn at Fig. 256 in section. The gully portion is much the same as any other gully, save that the lower portion is somewhat contracted, in order to enable the silt-box A to be lifted by means of the handle B, when the iron cover or grating has been removed. These traps are very useful, when fixed for cottage uses, with the scullery sink from the cottage or medium-sized house delivering over them in the outer air; and they are also valuable for the reception and disconnection of laundry wastes, it being impossible for any soap to enter the drain without being intercepted.

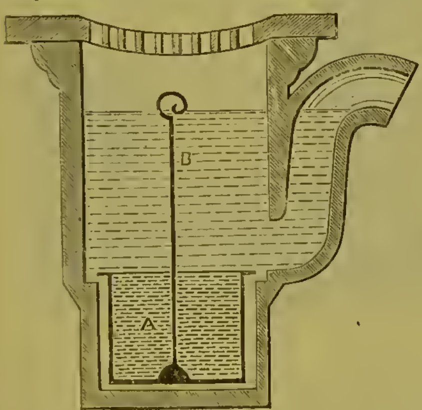

Fig. 256.

The yard and area gullies hitherto described, the traps of which, like those at Fig. 256, have deepened bottoms, are provided with these deepened portions simply to catch any sediment deposited from the waste water of the sinks, and for surface-water washings. But where there is no objection to such treatment, wire-made boxes are sometimes suspended over the waste from the sink, which is made to project through the wall over the gully-grating, and in these open wire gratings, tea-leaves, fish-bones, fruit-peelings, and the other many things which pass down a sink are intercepted—the basket being removed daily, and the contents thrown away in some proper place provided. There would be great use for a solid interceptor of this kind outside a very large establishment with many servants and a great quantity of viands to cook daily; but I see no necessity for such a complication in case of an ordinary villa.

GARDEN-GULLIES, ETC.

Whilst treating upon the subject of gullies outside a house, and in conjunction with house-drainage, I must not neglect to describe a gully-trap suitable for use in parterres, garden-paths, and private roads. These trap-chambers are generally built up of brickwork in cement, and fitted either with dip-stones, the grating being over the inlet portion of the trap; or, the trapping is formed by cast-iron dipping-pieces, which is attached by a screw to the iron frame, upon which is hinged the inlet and ventilated grating.

I have shown the latter form of trap in section at Fig. 257, as being the most complete arrangement for gullies of this kind, especially when placed in roadsides with a good declivity. It will be seen that there is a good collection-chamber for road detritus allowed for at the bottom of the trap at A, and that the trapping-chamber, which may be of any size to suit the exigences of each case, and the distances between the traps, is made easily accessible by means of the hinged grating cover B. Whether the outgo from these garden and private road gullies be into the house-drain on its way to the outfall, into a separate outfall, or into a pond or river, this species of trap is incontestably useful on account of its accommodating so much gravel and sand, which would otherwise enter the drain and clog it. It need not be feared that the sun would ever evaporate, in our climate, the depth of water between the bottom of the dipping-flange C, and the surface of the water at D. And speaking generally of all these gully-traps, it need not be feared that the trapping-water would freeze, this being rendered impossible owing to the difference of temperature between an underground drain and the open air.

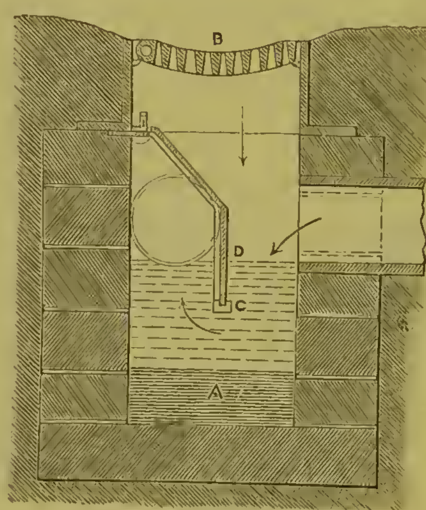

Fig. 257.

GREASE-COLLECTING CHAMBERS.

There is another kind of intercepting-trap, which I have found in my experience to be very desirable to provide in connection with the house-drain of any dwelling which can be classed above a large cottage, and is certainly indispensable in conjunction with a larger residence or mansion—I mean, an intercepting grease-chamber, especially prepared to receive the wastes of the scullery sink.

Many architects and engineers do not see any necessity for the collection of the grease which is delivered from large scullery sinks. Often, however, the absence of grease-chambers has proved a nuisance, necessitating even the taking-up a portion of the drains, especially in the immediate neighbourhood of the scullery sink.

It is certain that grease, when held in solution by hot water, will, after flowing through the trap dividing the sink from the drain, congeal the more and more as

it leaves the sink, and in due time fill up the drain, and necessitate the tearing-up of the flags, the making of openings into the drain, and the use of rods such as I have drawn at Fig. 249, and the like contrivances, to remove the encrusted fatty matter inside the drain. This evil state of things especially manifests itself when the scullery is situated at the far end of the drain, that is to say, at the point of the drain most remote from the outfall into the sewer, and also, when there is very little fall in the drain. It is not to be supposed that scullery-maids will carefully scrape the grease out of the pans and from off the dishes—on the contrary, they usually take a dish loaded with fat on its surface or in its gravy well-hole, place it under the hot water draw-off tap, and scour the whole of it down into the drain. On one occasion I noticed a cook skim the fat from the top of the stock-pot, and empty the fat directly down the scullery sink. No drain could be expected to work properly with such maltreatment as this.

Another reason for placing a chamber of interception in conjunction with the scullery sink is the necessity of catching and depositing the sand used for the scouring of pots and pans, and so preventing the sand from reaching the drain. Without a grease-chamber, the fat will clog the sides and any rough joint of the drain, the sand will become incorporated with the grease, and the whole will result in a mess. It is almost inconceivable what a quantity of combined material of this kind enters the house-drain from the scullery sink, in a large mansion. The difficulty is not removed by enhancing the sectional area of the drain, because this only produces more surface for the grease to fasten upon. When once the grease has lodged in the drain, no chemicals or any amount of hot water will solve it and pass it on to the sewer; and not the worst feature of grease-lodgment is due to the fact, that it offers an everlasting enticement to rats, those *ceaseless pests of unclean and faulty drainage.*

If the scullery sink were situated near to the outfall into the sewer, or disconnecting-chamber, the drain might be trusted, perhaps, to enter the latter without any interposed grease-intercepting chamber, especially if the waste-pipe were of an adequate size, and its fall into the disconnection-chamber a rapid one. But if the fall was insufficient, the result would be the same as far as the clogging of the drain goes, and would even be worse, because the grease and sand would fill up the syphon of the disconnection-chamber, with the resultant of a completely-stopped-up drain, with backed-up sewage.

According to careful experiments made by Dr. Russell, of Edinburgh, upon this subject, he found that without a grease-intercepting chamber of a suitable kind, and with a sluggish fall, as it is called, of the house-drain, the grease will deposit itself about three feet or a little more from the base of the scullery waste-pipe; with a somewhat better, but still insufficient fall, at a distance of about six feet from the waste-pipe; and that when there is a rapid inclination to the sewer, then at a distance not exceeding ten feet from the scullery sink.

In a long discussion which followed the reading of a paper by me at Newcastle-upon-Tyne, the majority of those present who spoke upon the question, and who were men eminent in their various professions, were of opinion that grease-collecting chambers became a necessity in some cases. It may appear at first sight that the provision of such chambers is a return to the old system of objectionable cesspools in connection with houses, but this is not so, for nothing should be

allowed to enter these receptacles but the scullery-sink grease and sand wastes. It is not wise even to allow rain-water from the roofs or yards to enter them, because such water does not readily pass through the layers of fat which float on the surface inside the grease-chamber.

It is of importance that I should describe several of these grease-intercepting chambers, and I will now proceed to do so. For a small house, where a household of ten or twelve, with two or three servants are accommodated, I would recommend the Doulton stoneware grease-collecting tank, which is given at Fig. 258, partly in section and partly in elevation. This grease-interceptor is made in two sizes, to contain about twenty-two and twelve gallons respectively. The inlet from the scullery sink is at A, where the end of the two or three inch waste-pipe rests, and for reasons aforesaid, the sink-waste should be trapped just underneath the sink. The greasy water delivered from the sink-trap enters at A, and in its passage down to the outlet of the chamber B, much of the fatty particles congeal and rise to the top of the trapping-water. The outlet into the drain is at C. No cover is provided with this pattern of chamber, but it nevertheless requires one, which can easily be made by any proper artisan, and hinged in the centre so that it can easily be lifted up for cleaning it out. It should be understood, however, that nothing should be thrown into the grease-chamber except the usual scullery-sink wastes. Provision should also be made for ventilating the chamber to a sufficient height in order to remove the steam, and to prevent its being given off into the scullery atmosphere.

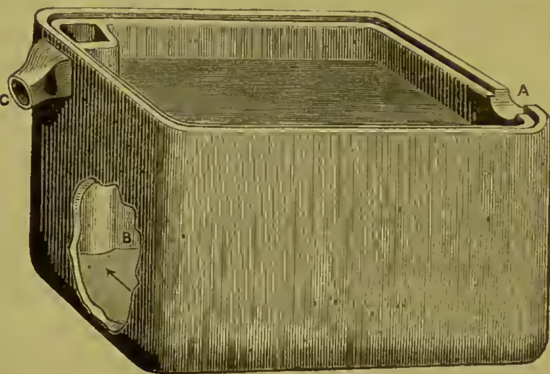

Fig. 258.

A larger-sized grease-intercepting tank, also of stoneware, known as Dent and Hellyer's pattern, suitable for larger houses, is shown in perspective at Fig. 259. Here the waste discharged into the tank rises from N to the surface, and the greasy matter rises up to the surface of the trapping-water, and is held there. The mouth of the outgo from the tank is at C. In order to clean the waste-pipe from the sink an access is made into it at D, and on the outgo of the trap a hand-hole is provided at E, in front of the mouth of the drain, for inspection or cleansing, and keeping the edges free from fatty conglomeration. A counter-sunk hole for ventilating the drain is made at F, and when not wanted, it is sealed over by a bedding-down cover. A ventilating arrangement for the trap itself (inlet) is also provided at G. When the drain has been cleaned out, and the layers of fat at the top removed, a brass plug and washer is sometimes provided as at K, and the use of this is that when

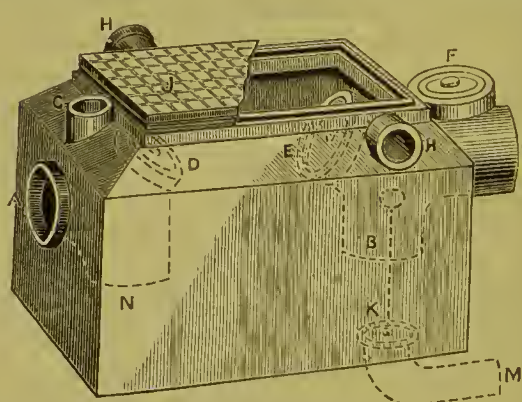

Fig. 259.

the plug is drawn up out of the dotted pipe M, the dirty water freed from its grease, empties itself rushingly into the drain and flushes it out. This arrangement also provides for cleansing out the drain, which is done by filling the tank a few times with hot water delivered from the scullery sink. The cover is of metal, and fits into a groove containing india-rubber packing. This cover is shown at J. Inasmuch, also, as outlet ventilation is required from the grease-chamber in order to remove the steam and decomposed gases, two outlets are provided from the tank at H H, and the outlet which is not the most convenient one to make use of can be closed up by a stopper provided for that purpose. It must be understood that the flushing-plug at K is not always available, because the drain may be too shallow to admit of a proper connection with the flushing outlet pipe at M, with its own syphon trap close behind it, and in such cases, that orifice can also be stopped up.

Preferably these earthenware grease-chambers are bedded under-ground, as far as the sides are concerned, and if properly used, and the cleansing of them understood, they prove cleanly to a degree. There are several other earthenware contrivances of this description, notably the Weatherly pattern, made by Messrs. Stiff, but I need not figure these. I have not chosen invidiously those drawn at Figs. 258 and 259, but have selected them as characteristic ones.

In very large mansions, and in large establishments, such as clubs, &c., where

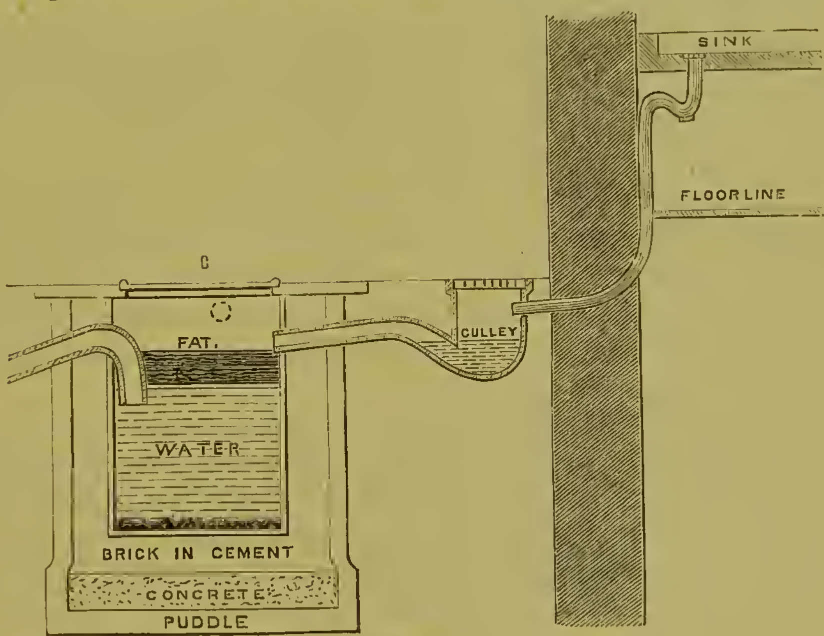

Fig. 260.

an excessive quantity of grease and sand passes through the waste of the scullery sink, these comparatively small grease-intercepting tanks are not advisable perhaps, and in such cases recourse is had to a grease-chamber formed of brick in cement, covered with a stone and ring, or an iron manhole-cover; the chamber being, of course, ventilated by a pipe. These ventilating-pipes should in all cases be led up to a sufficient height, so as not to ventilate the chamber at a level with any windows, &c.

The worst kind of this larger trap is that known as a Mason's or dip trap, where a dip stone divides the grease-chamber into two halves, and where the waste-pipe of the

scullery sink is trapped by dipping its end some few inches into the trapping-water on the house side of the trap. Such a kind of grease-chamber is not a cleanly one, and a far better pattern for large establishments is shown in section at Fig. 260. The scullery sink is shown with its access-trap, and with its delivery into the chamber. A ventilating-pipe provision is also shown, and an access manhole-cover at G. In most cases, it is sufficient to lead the waste from the trap under the sink to its outlet without interposing a gully, such as is shown. But where such a gully can be fixed close to the sink it is better, because the hot water containing the grease will pass into the grease-chamber before congealing, and there will thus be a good open-air disconnection between the sink and the grease-chamber. It is always preferable to provide proper air-tight-fitting iron manholes to these chambers instead of stones, with counter-sunk rings, on their upper surface. There are several very good patterns of these air-tight flaps in the market, and preference should be given to those that lock, and are hinged. The worst feature of these larger brick-built grease-collecting chambers is that, unlike the earthenware ones shown at Figs. 258 and 259, they cannot be removed as a tenant's fixture and taken to another dwelling. I should here add, that the pipes connecting the sink with the grease-chamber should be of lead, not less than three inches in diameter, as a rule; and this lead pipe should be carefully protected from rats, as I have frequently taken up lead pipes, laid underground, into which holes have been gnawed large enough to pass their bodies through. The best plan is to lay these underground lead pipes inside drain-pipes of the next nearest size, and fill the space in between with some material which will not act upon the lead.

These grease-intercepting chambers, where they have become an absolute necessity, should always be placed outside of the house walls proper; still, cases do occur, especially in town houses, where every available piece of open area ground has been appropriated, and there are no yards, and they must perforce be placed inside the house. In such cases every extra precaution should be exercised, and the chamber specially well ventilated. It is sometimes also very desirable to ventilate the sink side of the trap, underneath the sink, as well.

Whenever these grease-intercepting chambers have been deemed a necessity, and cannot be dispensed with upon any reasonable ground, the periodical cleansing of them becomes a matter of the utmost necessity; for if not regularly cleaned out, the edges of the outgo pipe get surrounded with grease, the grease—the objectionable matter in the trap—gets into the drain, and the whole business becomes a fiasco. The proper way is for the householder, or his representative in the house, to contract with a builder in the near neighbourhood, and engage that he shall clean out the chamber every one, two, or three months, according to the capacity of the intercepting-tank. Where this precaution has been taken, no mischief can accrue.

It is true that the floating and deposited wastes inside a grease-intercepting tank generate, during decomposition, very disagreeable smells; but, provided that the chamber has been ventilated whenever possible, such smells cannot enter the interior of the house. Of course when the chamber cover is lifted up, and the process of cleansing is going on, a very disagreeable odour is given out. But no one would attempt to clean out a grease-trap unless he had plenty of ground-lime, or some other suitable material, wherewith to neutralise the effluvia during the very short time which a clever labourer would occupy in performing the whole business.

CHAPTER LXIV.

SOIL-PIPES, OUTDOOR WATER-CLOSETS, ETC.

Soil-pipe Material: of Earthenware—Of Zinc—Of Wrought-iron—Of Cast-iron—Iron Soil-pipes in America—Lead Soil-pipe and its Advantages—Fixing Lead Soil-pipes—Should be Outside the House—Glass Soil-pipes—The Ventilation of Soil-pipes—Rain-water and Soil-pipes in One—Servants' Closets: a Bad and Good Pattern—Trough Closet—Country Cottage Closet—Urinals.

In the ordinary sequence of things, we now approach the subject of soil-pipes, which are perhaps the most important of the whole sanitary equipments in a dwelling. In order to do justice to the subject, it will be necessary to be somewhat prolix, because the material of which a soil-pipe is made, its position, its method of fixing, and its ventilation, have all to be separately dealt with.

As a matter of course, soil-pipes, or what acted as such, came into use at the same time as the water-closet; and it is not within the province of this section to enter into the more primary methods of withdrawing soil from upper closets, when the ancient dry methods of withdrawal were practised. This would lead into various antiquarian dissertations not germane to our subject. I will simply deal with soil-pipes as an appendage to the water-closets of the present day, feeling certain that they and water-carried sewage will prove the ultimatum of sanitation in this respect wherever any large community, or even any large establishment, is in existence. And this will be more and more recognised as closets improve in design and manufacture, as soil-pipe treatment is better observed, and as disconnection and ventilation of both are more recognised and practised. With regard to earth-closets and ash-closets, these do not come within the range of this subject.

I think there can be no doubt that the first soil-pipes, after the short reign of wooden shoots, were constructed of simply butt-jointed earthenware pipes, unglazed either inside or outside, and, in fact, little better than ordinary agricultural pipes of the present day. And while remarking upon earthenware pipes, I beg to say that soil-pipes made of such material are far from uncommon at the present day, only that they take the character of dirty glass, or salt-glazed, socketed earthenware conduits. In my opinion, such pipes are quite unfitted for such work, inasmuch as the commoner kinds of joints—which are mostly used—are liable to fracture at the biting, and even the pipes themselves to crack at the collars, or fracture perpendicularly, owing to any subsidence in the foundation or extra weight from above. Nor do the patent jointed earthenware or stoneware pipes fare any better. I had occasion to remove the whole stack of a soil-pipe from three closets in a costly house in the west of London, which had been placed in a chase in an inner quoin of the building with the very best motive, and found, after charging it with water, that it leaked at half-a-dozen joints, and that it had been crushed apart at the foot, where it joined the more rigid underground drain. Nor was this a solitary instance of the evil of choosing such weak material.

Another drawback to the adoption of an earthenware pipe is the certainty that the interior is not free from irregularities and ledges, which would in time arrest portions of the soil, and cause the soil-pipe to be badly encrusted with fœcal matter; and to sum up in a very short way, its inappropriateness as a soil-pipe, its disability as an exterior soil-pipe, with all its rampant ugliness of joint, open to the eye, has only to be mentioned in order to ensure its utter condemnation in that respect, however small the diameter may have been arranged.

Soil-pipes composed of zinc are very rare in London or large towns, but are more common in country places. I never met with but two examples. Such a material is totally unfitted to serve the purposes of a closet descent pipe, as it will speedily become perforated, and is, moreover, too rough in the interior and at the joints. I do not think there is a sanitarian alive who would advocate the adoption of zinc soil-pipes.

On many occasions, in town and in country, especially where such pipes have been laid in the immediate neighbourhood for special purposes, the unused excess of wrought-iron pipes have been adopted in buildings with a mere view to economy. But it need hardly be said that, owing to the exterior perishing and interior scaling of this metal, its suitability to act as a soil-pipe must be denied beyond all question.

Cast-iron is a material very much chosen for soil-pipes by many architects, engineers, and builders, and it will be worth a moment's while to give this selection a little consideration. There can be no doubt that its very general use as a rain-water-pipe led to its adoption as a soil-pipe, seconded, as the choice was, by the fact that it was a far cheaper material than lead. The misfortune, however, due to making choice of this material is due to the fact that, as a rule, workmen will not make a satisfactory joint. The vilest attempts at making a joint are perpetrated. Looked at, therefore, from a steadfast sanitary point of view, which seeks to eliminate all elements of a doubtful character, one cannot hesitate in scouting it as a material for soil-pipe uses inside a dwelling. And it may be taken as a safe calculation that if a common rain-water-pipe be used inside a house as a soil-pipe, an escape of sewer-air or drain-gases into that house is simply a matter of time. There is, moreover, a certain difficulty of jointing a closet-trap to this material, unless the work be executed by skilled workmen.

Even when a cast-iron soil-pipe is placed outside of the house, there are certain precautions to be taken regarding it which will bear repetition. For instance, the joint must not be of cement, or common red-lead and fibrous packing, but it should be lead caulked. And then, there are other precautions to take in regard to it. It should be in the shade, and not in the sun, as otherwise a fierce sun would cake the fluids inside as they dribbled down, and form the nucleus of an unwholesome obstruction. Then, again, there is the expansion and contraction, due to heat and cold, and a possible and wide alteration of the ventilating current. Above all, a cast-iron soil-pipe is liable to a great diminution in thickness as time rolls on, and nothing but incessant coats of paint will keep the outside of it up to the mark, even if the interior were not liable to corrosion by the action of salts. I have often had occasion to visit Paris, to inspect the cast-iron soil-pipes and ventilating-pipes, which are almost universal there, and I have very often found the joints unsafe, corroded, and giving off a foul smell. To remedy this, I have of late galvanised the pipes, both inside and outside; but I have lately come to the conclusion that the

Barffing or Bower-Barffing process, now common for the prevention of rust, should be applied to the interior and exterior of all cast-iron pipes used in any way for soil-conveyance.

In America, iron soil-pipes, preferably outside the house, are very much in use, and the regulations adopted by Boards of Health insist, in some cases, that every soil-pipe and waste-pipe should be of iron, free from holes, and of a uniform thickness, of not less than one-eighth of an inch for a diameter of three or four inches, or 5-32nds of an inch for a diameter of five or six inches; and for large buildings, the use of extra heavy pipe is recommended, the four-inch pipe of which scale weighs 13 lb., and the six-inch 20 lb. per lineal foot. And before such pipes are fixed, they must be thoroughly coated inside and outside with coal-tar pitch, applied hot, or some such approved substance. Before, also, they are connected with any fixtures, all openings have to be stopped, and filled with water for the space of twenty-four hours, in order to ascertain if there exists any leak or leaks. As for the joints in the soil-pipes, they are ordered to be caulked with oakum and lead, or with cement made of iron filings and sal-ammoniac. All joints, moreover, of lead with iron pipes should be made with a brass ferrule, caulked in with lead, the lead pipe being attached to the ferrule by a wiped joint.

It will be seen, from the above, that in America very strong precautions are taken in dealing with iron pipes as soil-pipes, and that the joints form an especial subject of care. I have lately seen some experiments made with Spence's metal in jointing cast-iron pipes, and they were really, in my opinion, very successful, and this material may some day be in common use for this purpose.

There can be no doubt that the best material for soil-pipes is lead. I would not, however, advocate the use of pipes formed of sheet lead, with a vertical soldered joint. It has been incontestably proved that pipes of this description are more liable to perish, inasmuch as the solder is of a softer nature, and nearly all the cases of bad soil-pipes exhibited in former days, as a caution to those concerned, were soldered pipes, the jointing of which had been almost completely destroyed. And unfortunately, also, the plumbers turned the smooth surface to the front, and the soldered portion to the inside of the chases in the wall, rendering it a very difficult thing to ascertain whether the pipe was sound or not. Nowadays plumbers are more cautious, and those of them who deal in home-constructed soil-pipes turn the white strip to the eye.

The kind of soil-pipe now adopted in best work is drawn lead soil-pipe, without seam, in long lengths of say twelve feet or more, and hydraulically tested. Despite this testing, I once came across a piece of pipe, new from the maker's, upon which the plumber and myself observed many white spots, and we had no difficulty in thrusting a common pin through the substance of the pipe into the interior by means of the finger and thumb. But I have never observed such a case since, and it was probably unique. Certainly, one has encountered sections of lead soil-pipe thin at one place and thick at the other, but now that improvements have been made in manufacture, such a thing is seldom, if ever, heard of. The ordinary thickness, or rather weight, of a soil-pipe is 7 lb. weight to the foot superficial, but this can be enhanced. As a rule, with the ample ventilation now accorded to soil-pipes, 7-lb. lead is sufficient for most purposes.

Lead forms the best known material, because of its interior smoothness, its

metallic compactness, and the easiness with which it can be bent by the aid of plumbers' dummies ; for at the present day the ordinary elbow joint is scouted, and bent joints patronised instead, by all who understand good work. Perhaps the most interesting exhibition of modern days was the plumbers' competition at the International Medical and Sanitary Exhibition, South Kensington, in 1881 ; and those who witnessed it must have been struck at the great trouble which was bound to be taken in making a soil-pipe with a double bend upon it, and at the ease with which some produced the specified bend in comparison with others. The art of bending a pipe and beating lead into any required shape constitutes the test by which a good or bad plumber is known.

THE FIXING OF SOIL-PIPES.

In fixing a soil-pipe, either inside or outside a house, and whether in a wall chase or otherwise, one of the chief things to look to is to see that it has been properly tacked to the walls. Tacks (see Fig. 261, A and B) are pieces of lead fastened upon the back of the soil-pipe, and fastened to the walls, in order to keep the pipes in their proper place, and prevent the weight of the soil-pipe from causing a detachment from the closet-traps, a disruption of the joints, or a falling of the pipe into the junction with the underground drain, which would, of course, block it up, and prevent the passage of the soil into the sewer. Tacks are either single or double, or alternate, and they should not be more than four feet apart. When the pipe is placed in a chase, the best way to make the connection of the two pipes is to solder the two pipes on the top of a wooden block, the lower pipe being spread out at right angles. The due rigidity of a soil-pipe is a matter of the utmost consequence. I examined a hospital in the north of England some years ago with about ten stacks of soil-pipes, and there was hardly a joint which was trustworthy, owing to the lack of these precautions, or to an insufficient attention thereto.

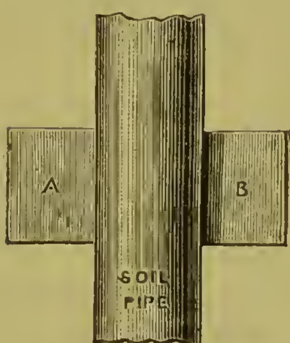

Fig. 261.

It is a very common mistake to choose soil-pipes of too large a diameter; they are frequently found in West End squares six inches in diameter, carrying the soil from two or three closets, whereas a pipe of three and a half or four inches diameter would have been quite sufficient. I have never made use myself of a larger pipe than four and a half inches diameter for five or six closets on the one tier of pipe, because the smaller the diameter of the pipe the more certain that it will be well scoured out. The same rule should obtain here as with soil-pipes of other materials; they should be kept as much as possible in the shade when on the outside of the house, and when they must perforce pass up inside the house, they should never be associated with hot-water pipes in the one chase.

There can be no doubt that soil-pipes, formed even of lead, should be on all possible occasions taken up outside the house, the branches from the P-traps of the closets or other connections soldered to the main stack outside. Occasions will doubtless occur when it will be apparently imperative to have some pipes, in the case of a large mansion, running up inside the house, and especially so when an old house is being altered; but in a new house no soil-pipe need necessarily stand in

the interior, and a way can always be found for placing this kind of pipe outside. They can always be made in such cases to resemble rain-water pipes, by fixing a clip over the joints in iron, or forming astragal beads; the top of the pipes can also be treated with a dummy rain-water head. So much trouble was found necessary in a house which I have seen in London, when the stack pipe necessarily descended in the staircase wall, that the owner had the whole lead pipe taken out, and an expensive copper one fixed in its place. This, however, was extravagance without adequate return, as nothing can be sounder than lead properly treated.

Some sanitarians have advocated the use of glass as a soil-pipe, because it is smoother inside, and because stoppages or lodgments in the pipe can be easier seen through its medium. But taking into consideration all the drawbacks which present themselves when considering glass, however thick, as a material for soil-pipes, the idea of using it as a soil-pipe must be set aside, at least for a very long time, or until at least some glass has been produced which will not fracture at the joint or be brittle throughout its length. The only kind of glass pipe at all fitted for soil-pipes is the glass-lined iron pipe made by the Glass-lined Pipe and Tube Company, in the State of New York. This consists of an iron pipe, into which a tube of flint glass, one size smaller, is inserted, the space between being filled up with a plastic non-conducting substance, and so overcoming the difference of expansion and contraction between the glass and iron. One would not be able to see into the interior of such a pipe, but they would have the satisfaction of knowing that there was a smooth interior, and that hot as well as cold water would pass down it without causing any trouble.

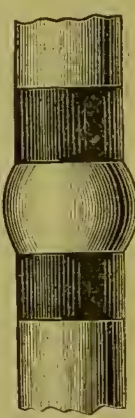

Fig. 262.

From the above, I think it may be taken for granted that drawn-lead pipe forms the best possible material for soil-pipes, and if the joints of such pipes are well made everything will be right. Care should be taken to see that the joints are not what are called slip joints, where one end of the pipe is slipped into the end of the other, and the space filled up with no matter what. Neither should the joint be what is called a copper bit joint, because it is a weak joint. The best joint for soil-pipe work is the wiped joint (see Fig. 262), and, in my opinion, this joint should be made by the plumber himself from beginning to ending of the operation. Before adopting, at all events, any so-called time-saving methods of joint-making, by casting around the joint with any material, the plumber would do well to be very certain that any such introduced joint is efficacious in every respect.

VENTILATION OF SOIL-PIPES.

A soil-pipe should always be ventilated, and sufficiently ventilated. The usual practice at one time, when the necessity for it was first mooted, was to take up a three-quarter inch or an inch pipe to the eaves of the roof. Later on came pipes of one and a half inches and two inches diameter, and then three inches and four inches diameter followed. At the present day it is almost universally admitted that a soil-pipe should be ventilated by a pipe of the full sectional area of such soil-pipe, and that this ventilating continuation should be carried up to a distance of about four feet, remote from a window or chimney-stack, and at least four feet above any window or dormer light; the top of the pipe to be protected from birds by some-

suitable cone. The only matter of controversy has reference to whether a closet which is situated on the ground floor, and has no closet above it, should also be ventilated to the roof-top with a pipe three inches or four inches diameter. My opinion is that it should be so ventilated, but that the diameter of the ventilating-pipe must be determined according to circumstances.

IMPROPER SOIL-PIPE TREATMENT.

Some persons, especially builders, ventilate a leaden soil-pipe by a ventilating continuation in rain-water down pipes joined together; but this is a very crude and objectionable method, as the joints are always precarious in their quality. And any builder will find, if he goes into the matter thoroughly, that he can erect lead pipe of light material suitable for ventilating-pipe for the same price that he can fix and properly joint a cast-iron pipe up the face of a wall. Zinc is a material not to be thought of for this purpose.

It is constantly a matter of surprise and disgust to notice, especially in modern houses built for the working and middle classes, how often rain-water pipes are made to do duty as soil-pipes as well; how often the waste-pipes from baths and sinks are taken into such combined pipes; how always these pipes communicate at the foot with the house-drain, not disconnected from the sewer in any way; and how very frequently such pipes doing double duty terminate level with the top windows, giving off a dangerous effluvia into the warmer room whenever the top sash is pulled down, or perhaps the bottom one lifted. There ought to be a stringent law passed against this pernicious practice, and all rain-water should descend to the ground, and deliver in disconnected fashion over the trapping-water of a proper gully. Some sort of a disconnection should also be practised with the soil-pipe. It may sometimes be a matter of convenience to take bath or sink wastes into a rain-water pipe which is open at the bottom, but it is far better to provide a separate bath and sink waste-pipe, cutting it off at the bottom, and carrying it up to the eaves, so as to obtain a current of air through it, and rid the pipe of the smell due to decomposed soap.

To conclude my remarks upon soil-pipes, nothing should ever enter these pipes but closet-soil, and the waste from urinals, and chamber slops.

SERVANTS' CLOSETS.

With regard to the water-closets inside the house, and all services in connection with the interior of the dwelling, this has been already entered into under the heading Architecture; and it will be sufficient for me here to say, in order to give coherence to the foregoing, that no closet should ever take the pan pattern, with its huge iron container and large D-trap, but rather the valve pattern, with lead P-trap underneath, or any of the many improved flushing-rim closets, made in one piece, with trap below. Leaden trays under these closets inside the house should have their wastes taken through to the outer air, with a small copper flap attached. The traps and valve-boxes are also best when they are ventilated by pipes separated from the soil-pipe; and when an overflow-pipe is attached to the basin, they should preferably be taken separately from the soil-pipe.

It comes within the province of my section to deal with water-closets outside the house for servants' use, inasmuch as such closets join the drain, especially in

country houses, at some distance from the residence; and even in town houses they should be outside the dwelling, and never inside, save, for instance, in the area, or in a front or back yard entered from the open air, and ventilated into it. As a general rule, servants' closets, being situated on the basement-level, do not require ventilating-pipes, although sometimes it is wise to provide them.

Fig. 263.

There is a form of closet which is in use almost universally in servants' retreats, and that is the common deep hopper closet, the flushing-water being led through a pipe at the top, where it simply twists about inside the basin until it reaches the syphon. The interior of this pattern closet, which is shown at Fig. 263, is always filthy in the extreme, and the flushing-water very rarely, if ever, flushes out the syphon, A. The pattern of closet which should be chosen is the flushing-rim basin, with a shallower body, and with a syphon having an access-cap on the top of the outgo, so as to enable it to be easily cleansed. There are many very good patterns of servants' closets in the

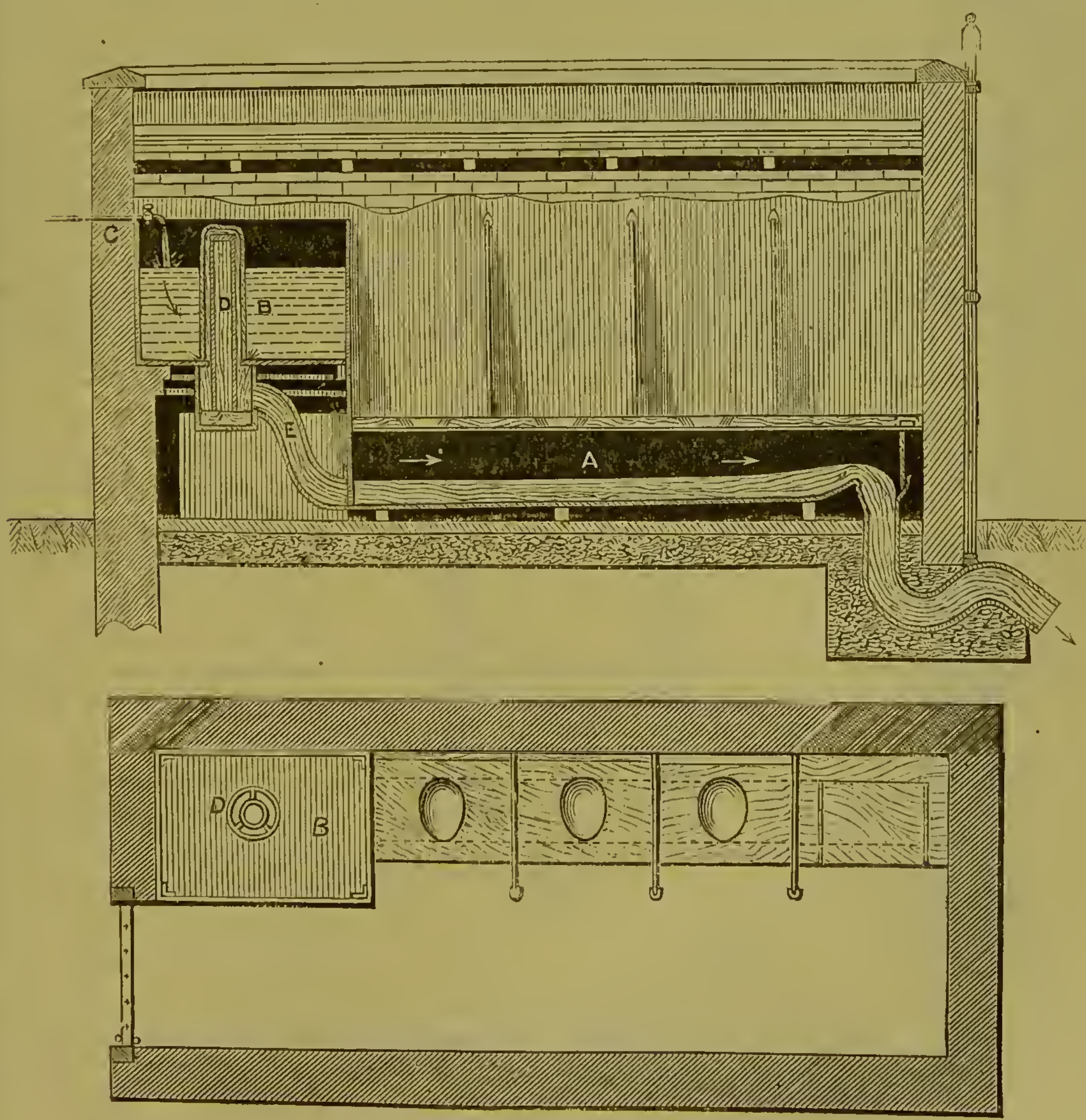

Fig. 264.

market, and this being so, it is quite reprehensible to use such a closet as that at Fig. 263; and no matter what pattern of closet be adopted of the wash-out pattern, they should always be flushed from a disconnection cistern with automatic action syphon inside, and separate ball-valve; the depending handle in connection with which requires only to be touched in order to deliver the whole of its contents of two or three gallons down the closet. A closet which is merely supplied from a cistern above, without the small flushing automatic delivery cistern just described, is very little better than a closet without flushing-water at all. As a rule, servants will not hold down the wire and ring sufficiently long to obtain an appreciable flushing, and the drain in the immediate neighbourhood, and beyond it, becomes blocked up in consequence.

Within the last few years a most excellent form of closet—where there are a number of male servants (see Fig. 264 for plan and sectional elevation)—has been devised, in which the basins deliver into a trough, A, and a due flushing is maintained by means of a cistern, B, fitted with one of Field's patent annular syphons, D, described later, which delivers itself automatically when full. This flushing-cistern is fed by a tap, C, which need merely dribble into it. The delivery of the contents is very speedy down the large waste-pipe, E, although it may take several hours to fill the cistern. And another advantage is that the delivery of water from the tap, C, into the cistern, B, can be so arranged that it will go off persistently, after any lapse of time, according as the quantity of water issuing from the tap is set. Thus, at any stated period of the day, say morning, noon, and night, or oftener, a certain number of gallons will sweep out the trough to the drain or sewer, without any person requiring to go near it for years. Fig. 264 shows a closet of this kind, manufactured by Messrs. Bowes, Scott, and Read. I have drawn it with only three closets, but of course it would work with others added. No doors are shown to the closets, so as not to complicate the sketch; but, as a matter of course, these would be fixed to each closet, and privacy obtained.

This kind of closet is also very suitable where many female servants, especially laundry-maids, are kept. The quantity of water consumed is little more than the total of what is used after every discharge of an ordinary closet *per diem*, and, in a manner of speaking, thrown away without benefit to either closet or drain.

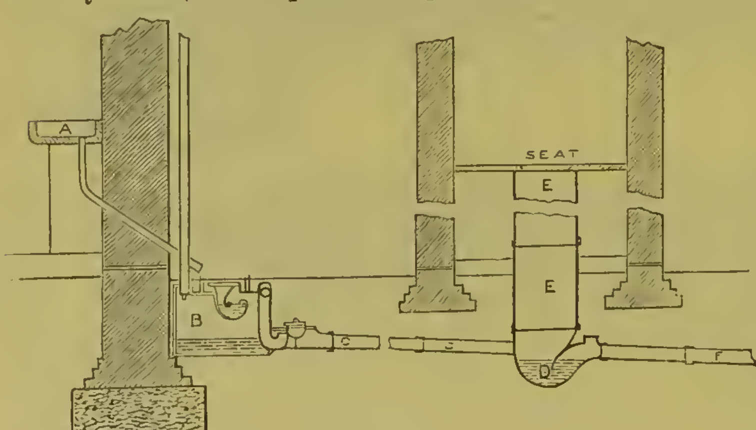

Fig. 265.

It often happens that there is no flushing-water to be obtained in country cottages for the use of the closet, while, at the same time, the wastes of the sink and washing-water would be beneficial in cleaning out any drain-pipe in connection with the privy, and be a means of taking the excreta to the garden, or to some place where it could be dealt with. I give a view of such a closet—also by Messrs. Bowes, Scott, and Read—at Fig. 265. The scullery sink is at A, and the flushing-tank,

which is another pattern of Mr. Field's arrangement, is at B. This tank when full delivers itself automatically in large volume down the pipe, C C, and clears out the syphon, D, and the soil which fell down the closet-pipe, E E, washing the whole contents down the outfall-pipe, F. This arrangement is far preferable to any kind of privy, because it utilises the slop-wastes, and, at the same time, keeps the closet clean. As a matter of course, with such a closet no basin must be used, and the sides of the soil-descent pipe should be kept clean.

URINALS.

An equally important thing about a household with a retinue of men servants is to have a proper urinal provided for their use ; and in these days of improvements it would be a folly to recur to the old stone sink, or to any pattern of this convenience which would not permit of an automatic discharge of some two or three gallons of flushing-water every few hours, so as to keep it quite clean. Treadle-valves are very apt to get out of action by wear and tear, and a continuous stream down the back of the urinal takes a considerable quantity of water during the day.

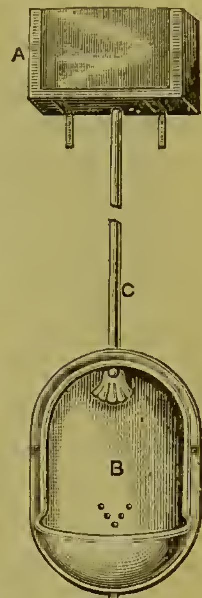

Fig. 266.

I show at Fig. 266 an ordinary urinal, having attached to it a pipe in connection with a small Jennings' automatic flushing-cistern, into which the very merest quantity of water is allowed to fall. When the automatic cistern at A is full, the water descends the pipe, C, full bore, passes through the spreader, B, and cleans the urinal from any offence. I have used this arrangement in hospitals with great success. All that is needful is to keep the flushing-cistern out of the reach of frost, and there can be no difficulty in doing this wherever the urinal may be fixed.

CHAPTER LXV.

DISCONNECTION AND VENTILATION OF DRAINS.

Definition of and Necessity for Disconnection—An Example of a simple Disconnection-trap—Improved Syphons for Disconnection-chambers—A General Disconnection-chamber for the whole Drains of a House—Syphons should be of less Diameter than the Drain-pipes—Rules guiding the Construction of these Chambers—Airtight and open Manholes—Examples of Disconnecting-traps at feet of Soil-pipes—The two Methods of Separate and Collective Disconnection—The Testing of Underground Drains and Upright Pipes, for Freedom from Leakage—Tidal Valves—Drain-flushing.

I now approach the subject of Disconneetion between the house and the house-drain or outfall beyond, and it is a matter of the utmost importanee that this should be thoroughly arranged. I have already pointed out how the wastes of sinks, lavatories, and baths should be disconnected in the open air, and also the feet of rain-water pipes. It may be taken as a safe and most general rule that nothing should enter a drain direet, a soil-pipe only excepted whieh has been duly ventilated. Every other waste-pipe shonld deliver in the open air, over or under a gulley-grating.

Within the last ten years or so, it has been often proved that a soil-pipe or house-drain cannot be said to be ventilated unless a current of fresh air be constantly taken into it, and as continuously discharged at the top of the soil-pipe or other special ventilating-pipe. Supposing, for instance, that a soil-pipe were trapped at the foot simply, and no eurrent of fresh air admitted between the trap and the soil-pipe, then this soil-pipe cannot be said to have been ventilated, for it will be full of foul air derived from the house-drain, cesspool, or sewer, and nothing in the shape of an extraeting-cowl fixed upon the top of the ventilating-pipes could have the effect of removing the foul air from the pipes.

The first publication of the neeessity of providing an inlet for air between the soil-drain and the soil-pipe or house has been claimed by several persons, and the controversy has led to an extensive series of artieles in the various sanitary and building journals. It would appear that Dr. Buchanan pointed out the necessity for this when at Croydon in 1875, and in a sketch whieh he furnished in his Report of the following year to the Local Government Board, he drew an upright air inlet-chamber between the house-drain and the sewer, with a view of supplying the house-drain with a current of fresh air, removing it by way of a ventilating-pipe.

Dr. Andrew Fergus, of Glasgow, also demonstrated, about this time, the necessity of replacing the foul air by fresh, and several patents followed; notably, those taken out by Buchan, Banner, and Potts. I do not mean to say that fresh-air inlets were not invented before the year 1875, but it was about this time that sanitary engineers began to insist upon their being provided. Mr. Dodson, of Glasgow, states that the system of air-inlets, with assisted withdrawal of such air in drain-pipes, was practised by him as far back as 1872. Soil-pipes, some twenty years before this time, were cut off at the foot, so as to get a eurrent of air through them, but no trap was provided.

A very complete idea of the action and usefulness of a disconnection-trap will be obtained by an examination of the Potts' Edinburgh air-chamber sewer-trap, one of the first which was brought into the market. It is largely used at the present time, and is doing excellent work. I give a view of this chamber at Fig. 267. The air-chamber, or inlet of fresh air, is at A, and the soil-pipe is shown at B; at L is shown a rain-water pipe, and at K, in the side of the air-chamber, is drawn a side opening for similar wastes requiring disconnection. An open grating over the air-chamber is shown at E, and between the upper grating and the chamber a second grating is provided, with the intention of filling it with charcoal, but, as a rule, this is now discarded. A division-plate is provided at G, with the intention of creating a current of air in the air-chamber. A small ventilating-pipe is also provided between the trapping-water of the syphon and the outfall-drain, with a view of ventilating the drain beyond the syphon; but it is not desirable to ventilate the drain beyond the syphon, against the house wall, beyond the outlet C. It will be seen from the sketch and explanation, that an air-chamber is provided between the trapping-water, D, and the waste-pipes descending from the house. All connection between the house-pipes and the external drains is thoroughly severed, and no drain-gases can be sucked into the house-drainage system, because, when the air in the house-pipes becomes warm, fresh air would be drawn through the grating E. As a matter of course, also, any foul air from the outfall, which may happen to saturate the trapping-water—a thing which very seldom happens—would escape up through the grating, and be dispersed.

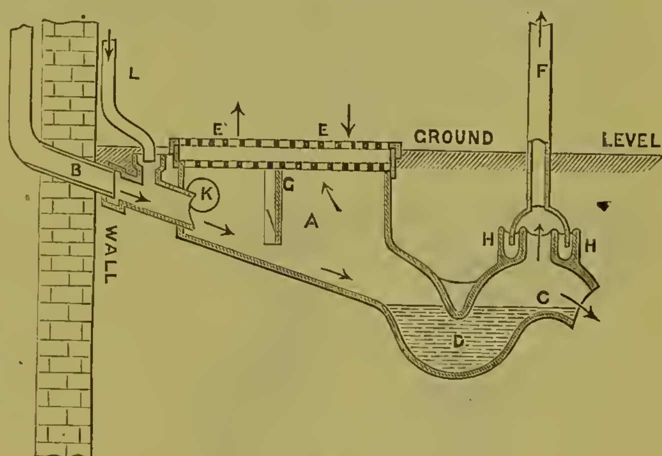

Fig. 267.

I will give an instance of some other forms of disconnection-chambers; but I wish to point out, before going any farther, that there are two or three sound rules connected with the use of these disconnection-chambers, which it would be well to point out. For instance, although it may always be done with impunity with such a trap as this, provided that the pipe were open at the top, it is unwise, from a high sanitary point of view, to lead the waste of a bath directly into the air-chamber, as shown at K and L. Clear wastes of this description from baths, clean water sinks, and lavatories, &c., should first of all deliver into an open gully, as shown at N, Fig. 269, the trapping-water of such gully discharging into the disconnection-chamber by way of pipes drawn above. This would be a wise precaution, because, after all, the soil from the closets must pass through the open chamber; and unless there be a sufficiency of flushing-water, the chamber will become somewhat foul. The sketch at Fig. 267 shows a very deep air-chamber, and it is sometimes impossible to obtain such an incline into the syphon; but the makers at Birmingham have lately provided various depths of chambers, so as to suit less rapid falls.

Many forms of improved syphons have been constructed, with a view of obtain-

ing an entry into the drain beyond the trap, in order that the drain can be cleaned out by means of rods or periodically flushed. And having seen by experience that it was wise to reduce the pressure of air against the water in the trap, at the foot of the disconnection-chamber, various forms of air-inlets have been devised, wherewith to ventilate the drain, between the trap and any ordinary open outfall. This thing ought especially to be borne in mind. When, for instance, such a disconnection-chamber arrangement as is drawn at Fig. 267 must necessarily be placed at a considerable distance from the house, fresh-air inlets, protected from vermin, should be provided, in order to give an accession of fresh air along the route of the drain.

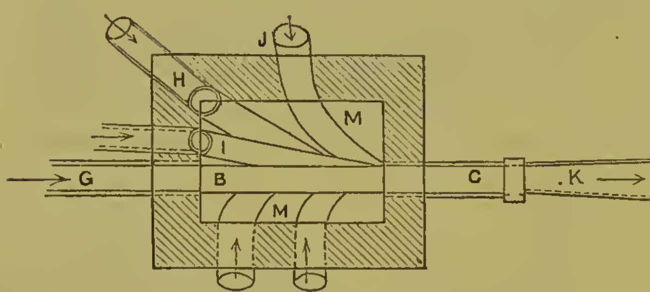

Fig. 268.—Plan.

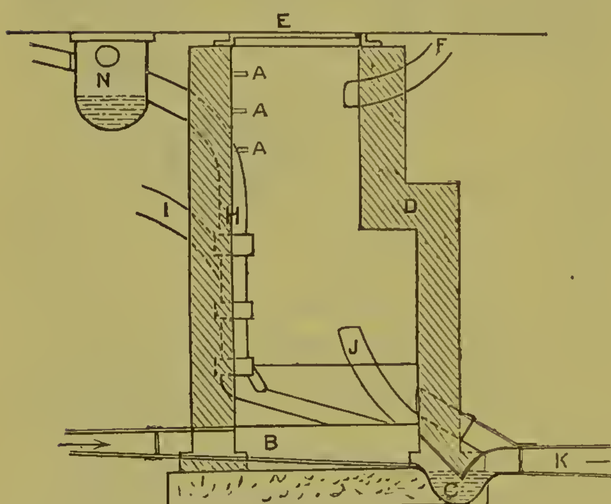

Fig. 269.—Section.

At Figs. 268 and 269 I give an example of a disconnection-chamber of another character, which is not sold complete in earthenware pieces, ready for jointing together, like the Potts' trap, Fig. 267, but is *built* up to suit a drain at some depth, say six, eight, or ten feet or more, below the surface of the ground. Fig. 268 is a plan and Fig. 269 a section, of an air-chamber of this sort. Here, the walls are formed of brickwork in cement, and, as will be seen, the shaft is just sufficiently large to permit a man descending it, by means of the Jacob's ladder-rings, drawn at A A. In chambers of these depths, and in order to provide a space for the whole of the main open channel, B, and the syphon, C, it becomes necessary to throw an arch over, as drawn at D. Within the last few years, in order to form cleanlier work than cement would make, half-open pipes, curved in every direction, have been made, in order to lead the wastes of outlying drains and closets, sinks, or back-yards and areas into the main open channel, B, which passes through the disconnection-chamber. Some of these curves, designed by Mr. Field, can be seen on the plan, Fig. 268. In such a case as this, where the drain lies so deep, especially if it be near the house, it is found mostly advisable to cover over the shaft with a close iron manhole at E, and to lead a current of fresh air into the chamber—for instance, at F—by means of a six-inch pipe, conveyed to the nearest wall, and connected with a twelve-inch open grating, built some foot or so above the ground (see F, Fig. 272). The fresh air, thus admitted, would pass up the drain-pipe G, Fig. 268, along the drain, and be discharged by way of the ventilating-pipes at the end of each ramification of the drain.

In building disconnection-chambers of this description, it should be borne in mind

that no pipe should deliver its contents from a height above the open channel; but, on the contrary, the pipes should be led down so as to deliver on the top of the main open channel. This can be done either by bringing the pipes down inside the chamber, as drawn at H I, or by leading them down outside the wall, as shown at J. If this rule be not rigidly observed, the sides of the air-chamber will become foul, and generate unhealthy smells. The tributary open pipes, whether straight or curved, should, moreover, deliver their contents—not level with the bottom of the main channel B, but on the top of it, as shown; by this means obtaining for the wastes a certain cascade action, beneficial alike to both channel and syphon.

Figs. 268 and 269 exhibit some further points of some consequence to the constructor of a disconnection-chamber. For instance, a syphon, with a raking-inlet pipe cast upon it, is drawn at C. This inlet-pipe affords a ready means of cleaning out and flushing the drains, as before described.

Experience has taught engineers that a syphon trap should always be of less diameter than the main drain in front of or beyond it. For instance, the six-inch drain from the house at Fig. 269 is made to deliver into a four-inch syphon, and beyond the syphon at K is shown a tapered pipe to lead the wastes, which have passed the syphon, back again to the six-inch drain, leading to the outfall. In some cases, a six-inch pipe may deliver through a six-inch syphon. Certainly a nine-inch drain should never deliver into a nine-inch syphon. As for a twelve-inch pipe, it should never deliver into anything but a nine-inch syphon, but the necessity for such large pipes as that last mentioned is seldom to be thought of for house-drainage.

When the drain is a shallow one, of course the turning of an arch over the open channel of the disconnection-chamber is not necessary, and the wall would be carried up to the surface from about the middle of the syphon, where the raking-inlet terminates. With chambers that are thus shallow, the cleanliest practice is to build the chamber with glazed brick facings to match the glazed white channeling below. The splayed bed from M M to the channels can be sufficiently well treated with fine cement. When the disconnection-chamber is being built, it should be built with brickwork in cement, upon a bed of concrete; and when there is any subsoil-water to deal with, the walls should be puddled outside with clay, so as to prevent ooze and discoloration.

In Fig. 269, the entrance to the disconnection-chamber is covered with a closed iron manhole, and in order that there should be no objectionable circulation between it and the air-inlet, F, it is necessary to provide a manhole-cover which should be perfectly air-tight, and require no periodical charging with water or with sand, where the dipping piece of the door fits into the groove of the iron frame. It is also essential that this manhole-cover should be kept locked, and a locking apparatus and suitable key are therefore advisable. When it is open it is advisable also to be able to throw it over its perpendicular, or provide it with a proper strut, so as to render it impossible for the door to descend on a man's head.

A very recommendable example of a hinged air-tight manhole-cover, and one very generally used, is drawn at Fig. 270, and is known as Angell's Patent, London. The flap is rendered air-tight when closed by the flange A, which runs entirely round the inner side of the frame, as shown at Fig. 371, and which presses itself into a packing of suitable material, which is fixed in the groove formed in the under side of the flap at B. There are other air-tight manhole-covers in the market,

which either lift up or lock, among which may be mentioned that of F. Dyer, of London.

When the disconnection-chamber is not placed in too close proximity to the house, or not inside a yard surrounded by walls, it is very advantageous to make

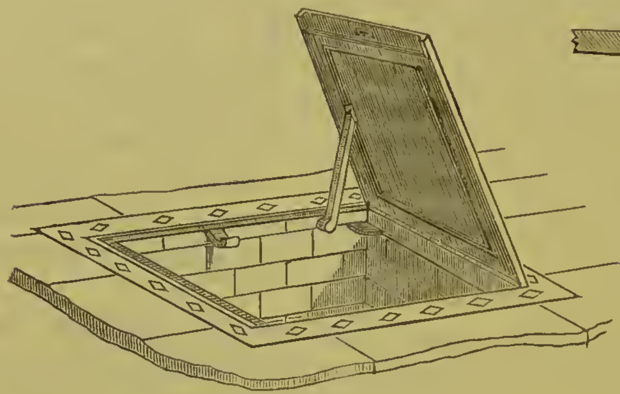

Fig. 270.

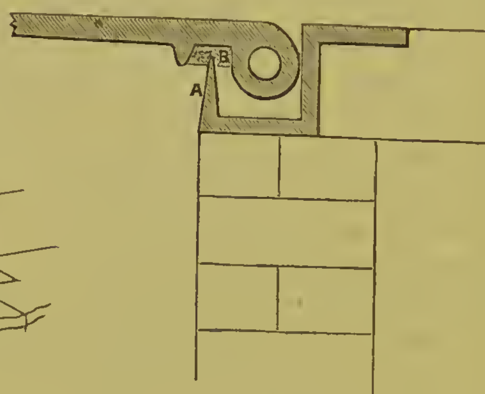

Fig. 271.

use of a manhole-cover with an open grating. There are of course many patterns of this kind, and they may be either made to lock or otherwise. It is better to have them made so as to lock, and they should be, moreover, sufficiently strong to allow a cart to pass over them without fracturing them.

As open manhole-covers of this kind are frequently placed in fields, the necessity for locking them is all the greater, because cattle, placing their feet on a corner of an unlocked grating, are apt to tilt it up. Open gratings of this description should be fitted up with a mesh of copper wire under the grating, so as to prevent the entry of leaves. Excellent, although differing, examples of open gratings suitable for the above purposes are manufactured by Purnell, and Bailey & Co., of London.

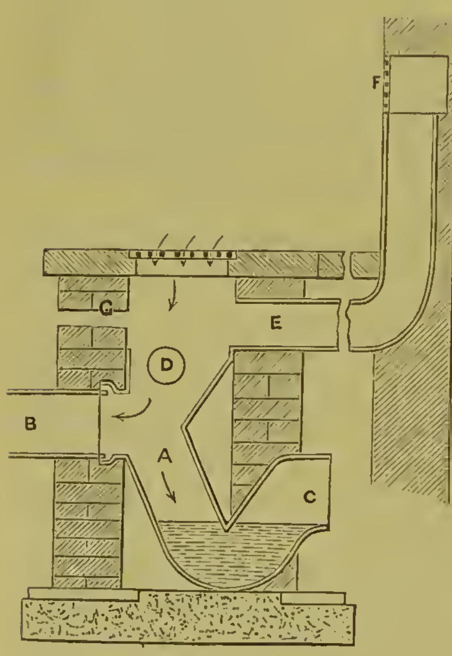

Fig. 272.

It has been found very frequently that a much simpler method of disconnection is desirable than that shown at Figs. 268 and 269. For instance, in the case of a cottage or small house, an open channel pipe, two or three feet in length, makes the construction of the chamber somewhat expensive. Many syphons have been devised with a view of providing for such cases, and Weaver and Hellyer's traps are very good examples of these. In order to show how a syphon of this description can be made to act as an inlet, even at some distance below the ground-level, I draw one at Fig. 272. Here the syphon itself is drawn at A, B being the inlet from the house, and C the outgo to the sewer; a side entry, or an entry for inlet ventilation, is drawn at D. The whole syphon is surrounded by brickwork in this sketch, but it is not absolutely necessary to take the brickwork down to the bottom of the syphon, as the

latter has a spreading piece or cradle, to enable it to be fixed in concrete. An inlet-grating is here drawn instead of a close-fitting cover, and where this is not objectionable it is the best way of bringing in fresh air. Should a closed manhole-cover be used, then the fresh air would be brought in by the pipe E, which is a four-inch pipe of earthenware or iron, chased in the nearest wall, and fitted with an iron grating, at F, some foot or so above the surface of the ground.

When there is the slightest likelihood of a back-draught being encountered from the house-drain from any imagined cause, or should the inlet of air be closely opposite a basement window, it is customary to fix, flush with the wall if possible, a mica-valved inlet, such as manufactured by Comyn Ching and Co., or Dent and Hellyer. One precaution should always be taken, and that is, to take the inlet of air in front of the house delivery as shown at E, and not, for instance, at G.

It has become very common of late to fix at the foot of each soil-pipe a disconnecting-trap, with fresh-air inlet into the same syphon, and these disconnecting or intercepting syphons take various forms, but all more or less resemble the earthenware portion of the disconnection arrangement drawn at Fig. 272. I have already mentioned the Weaver and Hellyer traps, but beside these there are the Belham trap, and the Doulton trap, both furnished with soil-pipe entries and with ventilating uprights. Some have provisions for raking and flushing out the outfall-drain in the syphon itself, and others have not; but whenever a syphon is unprovided with a raking-inlet to the drain beyond the syphon, either such a raking-pipe should be fixed to an upright Y junction in a drain-pipe just beyond the syphon; or a manhole should be provided, some still farther distance from the syphon, which would enable a workman to cleanse out the drain with rods. The syphons, in these cases, should dip at least three inches (if possible), so as to afford a sufficiency of hydraulic seal. Some persons have considered it necessary to construct a double syphon, that is to say, a syphon beyond the one syphon shown in the above figures. Mr. Woodhead's double syphon, ventilated trap, manufactured at Leeds, is an example of this kind. I do not myself think these double traps necessary, provided the outfall-drain beyond the syphon is properly ventilated. Moreover, two syphons placed thus together require more fall than can be afforded in the great majority of cases. Among the traps of this kind especially fitted to receive the soil-pipe immediately at its foot, I may give the Buchan trap, drawn at Fig. 273. The advantage of this trap over several others is the extra fall from the level of the house-drain at A to the surface of the trapping-water at B. This extra fall assists in stirring up any sediment in the syphon, enabling it to be washed out to the outfall C. A syphon having a throw-off lip is also manufactured in London, known as Angell's syphon, and it possesses the faculty of throwing the water nearer the middle of the syphon

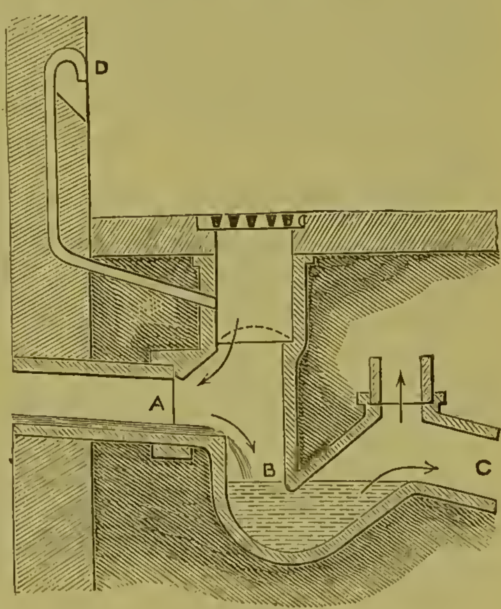

Fig. 273.

and of pushing the soil, etc., outside. Sometimes it may happen that the open grating over the ventilating-inlet of a disconnection-chamber or ventilating-grating may be covered with dirt or snow, and it is very evident that some supervision should be extended to open horizontal ventilators to see that they are shielded from such a mishap. Sometimes, too, when the disconnecting-trap is placed at the foot of the soil-pipe, a blow of foul air may be swept into the open air by the passage of a strong wind across the ventilating-grating. To provide against this, and also the filling up with dirt or covering with snow of the ventilating-inlet, Mr. Buchan has devised the small pipe-entry underneath the grating, as shown at D.

It will be seen from the foregoing descriptions that there are two methods of practising the disconnection and ventilation of house-drains. One is, to fix at the foot of each soil-pipe, or drain-collection, such traps as I have given at Figs. 267, 272, and 273, taking fresh air immediately up the soil-pipe. Nothing can be said against this method of disconnection and ventilation, except, that if it be rigidly practised, at a large establishment, for instance, the traps will be required in considerable number, and the underground drains outside of them will be left without disconnection.

Traps of this description have been, however, undoubtedly devised with a view of immediately severing the house-drain, or soil-pipe, from the drain beyond; and the practice introduced by Mr. Norman Shaw is very similar, except that he delivers his soil into the hopper-head of a cast-iron pipe just outside the closet, and so obtains a current of air through the pipe from the inlet of the syphon below to the hopper above. The other system of disconnection and ventilation is that given at Figs. 268 and 269, where one disconnection-chamber is provided for the whole house, and everything is made to pass through the open channeling. Of course, where there are two outfalls two disconnection-chambers would have to be provided. In this last-mentioned method of dealing with water-carried sewage, the ventilating-pipes on the roof, whether soil-pipe continuations or separate ventilating-pipes, all derive their air from the ventilating-inlet at the disconnection-chamber.

Such a single disconnection-chamber is generally fixed where the house-drainage from various points can be led easily into it, and it will be found in practice to afford more advantages than separately disconnecting each soil-pipe. It must be borne in mind, however, that, although the traps drawn at Figs. 267, 272, and 273 are adapted for fixing close to the feet of the soil-pipes, such traps can be made to disconnect drains when they are fixed at some distance from the house, and thus act as a kind of ventilating-chamber.

For general work, I should prefer the roomy open channel, shown in plan at Fig. 268, with a raking-pipe to the syphon, and a manhole sufficient to permit a workman to examine the trap and clean the drain out both in front of and beyond the syphon.

When the drains have been laid upon their concrete bed inside the house, and before they have been covered over with concrete, it is most essential that they should be tested for soundness of joints. The crucial test in this case is to fill them with water after stopping up the lower end of the drain outside the walls of the dwelling.

By way of testing the efficiency especially of the upright pipes of lead

or iron which descend either inside or outside the house, from closets, slop-sinks, &c., it is advisable, once the disconnection-chamber has been fixed, to test the soundness of these pipes and their junctions with the already water-tested drain, as well as the efficiency of the ventilating arrangements, by burning some material in the open channel of the air-chamber, which will produce a considerable amount of smoke, the pungency of which will make itself manifest at any faulty joint. The advantage of this method of testing a drain or upright pipe is that a weak place not only discovers itself to the sense of smell, but also to the organs of sight.

Another common practice is to pour down the top of the farthest ventilating-pipe in connection with the disconnection-chamber about half an ounce or so of (Mitcham's) oil of peppermint, taking care to pour down immediately afterwards about six gallons of hot water. If there be more than one ventilated soil-pipe, then the rest should have been previously stopped up in a temporary fashion, as should also the ventilating-pipe which is operated upon immediately after the hot-water discharge has followed the oil of peppermint. The doors and windows into the house should also have been carefully closed previously, and as much as possible the rooms where no pipes descend isolated from the rooms and closet-spaces where they do descend. By this procedure the smallest leak will be instantly discovered by the various persons stationed simultaneously in the places where the pipes descend, and the weak spots can be marked with a piece of chalk. Any other essential oil derived from a strong-smelling plant, and some of the disinfectants, will answer the same purpose; but care should be taken that none of those persons who are told off to discover the presence of any leak on the various floors are allowed to handle the peppermint, nor should the bottle containing it be opened until the operator is on the roof. Neither should he traverse the rooms undergoing the test until the matter of leaks or no leaks has been decided, the odour given off by such oils being so volatile.

The testing of pipes by essential oils from the top of the roof downwards is a very severe test; equally severe is the smoke-test from below upwards, and a still more searching test is the burning of a quantity of sulphur in a shovel at the mouth of the disconnection-chamber or drain just outside the house. When testing from the air-chamber with smoke or sulphur fumes, the inlet ventilator should be properly closed after the light has once been applied.

From a perusal of the above few remarks regarding the necessity for and the methods of achieving the disconnection and ventilation of house-drainage, it may be imagined with justice that the wisest way for the householder who desires to obtain all the benefits of this modern system of drainage, would be to consult some professional man before obtaining a tender or proceeding to carry out the work. For far too frequently, after an ordinary builder has produced what he terms disconnection and ventilation on modern lines, the bulk of the work has to be re-arranged at considerable expense.

It not unfrequently happens that, after passing the disconnection-chamber just described, the further delivery is into an outfall subject to intermittent flooding or rising tides, and in such cases it becomes imperative to prevent the inroad of the flood or tidal water into the drain-system. The necessity for traps of some kind, which should check the ingress of such unwelcome water, has been felt as long as

water-borne sewage has been introduced. Formerly, people were satisfied with flap-traps, but they required such heavy weighting that, after the subsidence of the waters, the flaps did not easily open to permit of the sewage delivery. The first engineer who devised a trap suitable for resisting the inroad of waters was Mr. R. Rawlinson, C.B., and this was in 1854. It was by means of a rising ball in the upright pipe, connected with the drainage. This idea was taken hold of in 1863 by Mr. Tenwick, who constructed a separate chamber with a floating valve and an elastic seating. In more modern times, Mr. Young's valve-chambers were introduced into the market, and combined with Mr. Clarke's improved gullies, both being manufactured in Carlisle. For the purpose of preventing the back-flow

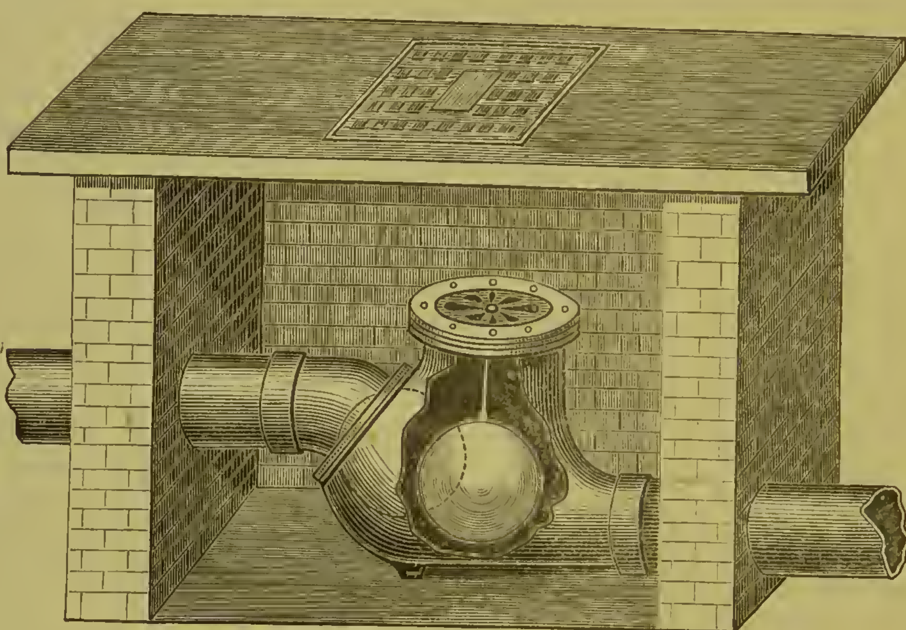

Fig. 274.—Back-flow Trap.

of sewage from drains, when these have been laid in low situations, and subject to flooding, nothing can be better, and they are indispensable in the cases of cellars lying under the line of the sewage exodus. The value of this particular contrivance is that the valve-chamber, which contains the copper ball and chain with india-rubber hood, can be connected with an ordinary gully in any position, and the ball is so adjusted and guarded that it cannot possibly fail to find its proper seating. Messrs. Jennings, of Lambeth, also contrived for me a resistance-trap of this description, and it has succeeded in keeping back a heavy sea-water.

It may be useful to illustrate and explain the action of a modern valve-trap of this description, and I therefore furnish at Fig. 274 a trap-chamber complete, fitted with a rigidly-hung ball, it being found that, under certain conditions, a chain is liable to become deranged. The action of this trap, which is manufactured by Mr. F. Dyer, of Camden Town, London, is as follows: The backwater, after entering the outgo pipe, rises in the chamber, and causes the ball to float and seat itself firmly upon the orifice connected with the house-delivery pipes. By this means, water is prevented from entering the house-drain, and the greater amount of

pressure there is behind in the outfall opening, the more securely sealed the trap becomes.

As a matter of course, these traps should be used with caution, because, should the flood last several days, the house-drain might not be able to accommodate the resulting sewage, in which case it would be necessary to provide a pump, so as to assist in emptying the drain; and this would be especially necessary when the rain-water from the roofs and courtyards were taken into the drain along with the effete wastes.

I have now brought the practice of house-drainage up to the disconnection-chamber, beyond which everything becomes an outfall treatment. But it would be

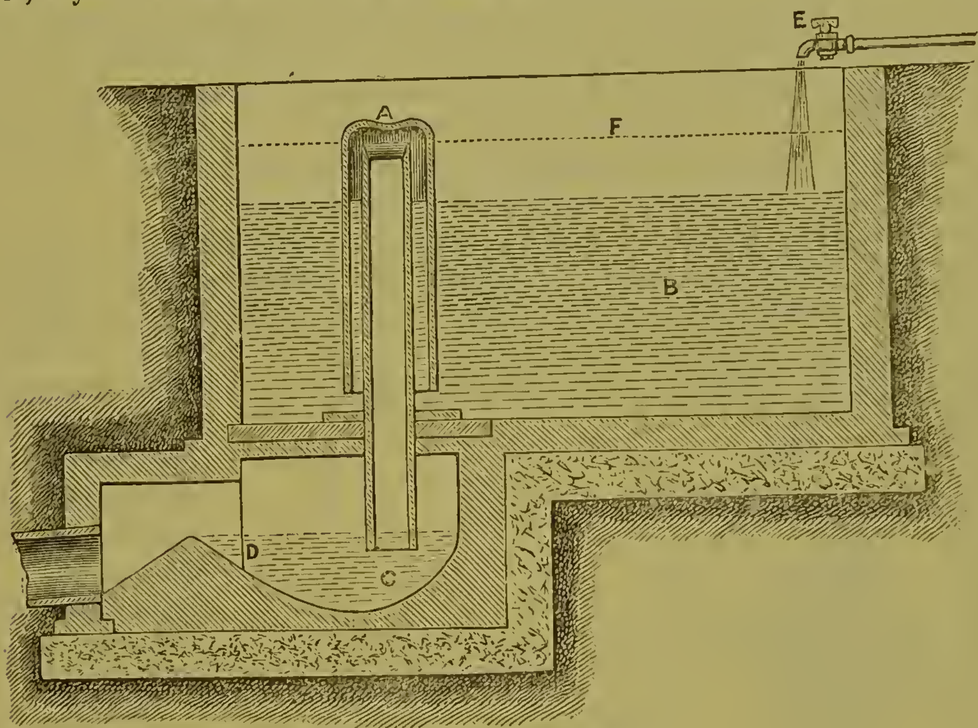

Fig. 275.—Field's Flushing-tank.

wise to interpolate here a few remarks with regard to the necessity for providing a means of flushing out the sewage-pipes, and, for the matter of that, the twin drains, when these are introduced—the one for foul wastes, and the other for rain-water and the cleaner wastes. Such flushing-apertures should be provided at most of the junctions or manholes, as very frequently it becomes an easy matter to introduce a hose from a near-lying hydrant. It can readily be seen that even buckets of water can be used for flushing purposes, always provided that entrances into the drain are duly arranged for at the head of the drain. The best way of flushing out drains is, however, on the automatic principle, where a tank is provided which shall periodically deliver its water through the drain, so as to sweep every obstacle before it. There are many contrivances of this kind, and I have used many of them with advantage; but it will suffice if I instance a tank of this description, for use either below or above ground, which will discharge 20, 50, or 100 gallons of water when it is full.

The best example of a flushing-chamber of this description is that of Mr. Field,

made by Bowes, Scott, and Read, of Westminster, and illustrated at Fig. 275. This represents an underground tank, in which a syphon is fixed, the longer limb of which dips into the water below the tank, which water is kept at its proper level by the weir marked D. In this case, the water-feed is from a tap at E, in connection with some convenient cistern, or water-supply, of any kind whatsoever; and the merest dribble, so to speak, from the tap will suffice for the action.

The action is as follows:—When the water accruing from the tap E rises to the top of the longer limb of the syphon, shown by the dotted line F, instead of running down the sides, it is guided by a throw-off lip at the top of the annular space, and descends clear of the sides, by which means the air is displaced, thus gradually and with certainty forming a vacuum in the discharging limb, thereby starting the syphon A, and emptying the tank B by way of the discharge C over the weir D. This flushing-tank is remarkably useful where the house-drains are very flat, and, when properly placed, will suffice to forward the sewage to a great distance, inasmuch as the discharge-pipe can be made of any diameter.

I will furnish further on a more lengthened description of its uses when dealing with irrigation-matters. Flushing-tanks serving the same purpose are manufactured in other parts of the country; and in Ireland, that of Maguire has met with considerable commendation. To Mr. Field, however, is due the conception of the annular syphon, drawn as above, which combines the certainty of action in a minimum of space.

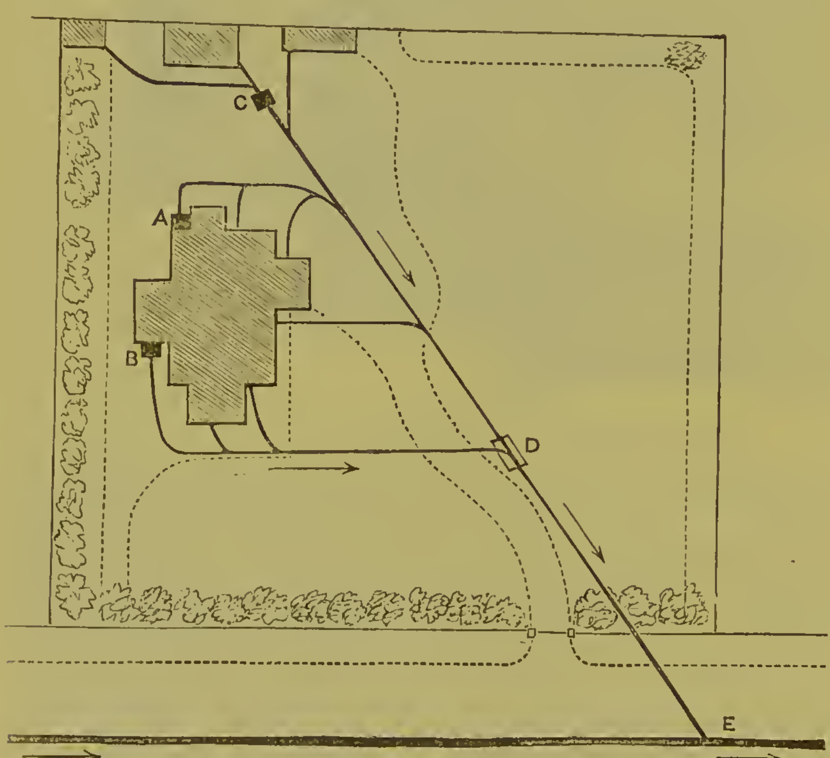

Fig. 276.

In order to indicate the beneficent action of these self-acting and periodically-delivering flushing-tanks, which require no attention whatsoever, and which discharge their contents every time they are full, I give at Fig. 276 a block plan of a house showing three such automatic flushing-tanks. For instance, A may represent an underground tank, receiving the wastes from housemaid's sinks, baths, and lavatories; B may represent the collections from certain ground-floor sinks and rain-water pipes; and C may represent a tank intermittently filled with laundry discharges. When these tanks are full, the whole of the drains on

their line of march will be kept clear, the disconnection-chamber at D will be kept well flushed out, and the sewer E consequently benefited. It should be understood, however, that no soil from any closet should be led into these flushing-tanks, and that bath, sink, and the other cleaner wastes should deliver over a gully disconnectedly in the open air before entering the tank. It can easily be understood that these flushing-tanks can be fixed at the top of the house, so as to cleanse out the upright soil-pipes as well.

CHAPTER LXVI.

DRAINAGE MEMORANDA.

The Drainage of Stables—Closed Underground Pipes—Iron Surface Pipes—Open Stone Channeling—Drainage of Piggeries, &c.—Rules for the Laying-down of Drains—Notes with reference to Soil-Pipes, Closets, Sinks, and other sundries.

Before proceeding to deal with the outfall of the drains, it would be wise to interpolate here, in a somewhat compact form, the rules which should guide the laying down of house-drains, and the attention which should also be given to them.

STABLE-DRAINAGE, ETC.

I have not considered it necessary to deal specially with the stables, although in point of fact a stable-building may be called a portion of the mansion. It will suffice to say that on no account should the stable drain itself into the house-drains above the disconnection-chamber, because, if this be done, the smells peculiar to stable-dung will traverse the house-drain. There would be no harm in leading the stable sewage into the drains coming from the house below the disconnection-chamber, where fresh air is taken in to the house-drain. Even then, however, the stables should be disconnected from the drain by any of the many intercepting or disconnecting traps now in the market, and the head of the stable-drain should be duly ventilated by a pipe led to the roof.

People differ very greatly as to how a stable should be drained. Some make choice of underground pipes, with horse and mare pot traps, and with a central gully to receive the swilling-water; and others prefer the iron surface channels, manufactured by the various founders of stable-fittings. These last mentioned perform admirable service when they are kept clean, but the slightest slovenliness in the character of the groom, and any neglect of cleansing out these iron gutters, will result in a filthy condition of the channels, which will make itself felt to the detriment of the animals.

One of our most eminent owners and breeders of horses had in his large country establishment the whole of his stables drained with iron open channels, with movable coverings in sections; but he has lately caused these to be removed, and has laid down simple stone surface channeling, entirely on the score of cleanliness. And there can be no doubt that the washing-out of these open channels daily into the gully outside the stable door, which is in communication with the drain, is the simplest, cheapest, and cleanliest fashion extant.

As with the stables, so with the piggeries—for it is not unusual to find these not far removed from the stables—the same rule as to the necessity for disconnection especially holds good; and if there be a liquid-manure collection for garden use from the stables and piggeries, &c., a disconnection-trap between becomes an imperative necessity, as does also the ventilation of the tank itself in some suitable manner.

The same law would hold good with regard to heneries, or any place where

manure is formed, and where the swilling-water used for cleansing the floors is led into the drain.

The floors of all these accessory buildings should be perfectly water-tight, supplied with a tap, to which a hose can be attached, in connection with a cistern placed at as high an elevation as possible. The above remarks may be deemed in excess of what is really required; but it is proved that animals are as subject to filthy diseases as men, and that the drainage of a stable or piggery should be as perfect, at least, as the drainage of a courtyard or area of a dwelling.

GENERAL RULES REGARDING HOUSE-DRAINAGE.

The general rules which should guide the laying-down of house-drains may be gathered from the following memoranda :—

In laying down house-drains, it is of the utmost importance to secure a solid bed; and when once the gradient has been chosen, a belt of concrete, some three or four inches in thickness, should be laid down at the bottom of the trench, and the pipes laid thereon.

When the pipes have all been laid upon this concrete bed, every joint carefully luted in cement, they should be tested for soundness by filling them with water. This water-test should not be proceeded with, however, until the cement has become thoroughly set. If it becomes necessary to cover the pipes quickly, then some other method of testing should be resorted to, such as the smoke, the burning sulphur, or the peppermint proofs.

When the pipes have been proved to be thoroughly sound, they should be covered over with a few inches of concrete in all cases where they pass through the house.

Where house-drain pipes pass through the walls, it is wise to turn a relieving-arch over them, free of the pipes, in case any settlement should take place in the building; for should this occur, the pipes will crack, and a consequent leakage take place with dangerous results.

All pipes chosen for house-drains should be of the glazed order of earthenware pipes, and all porous pipes should be avoided. Pipes without sockets should on no account be used.

When junctions are laid down, preference should be given to the Y-shaped junction, and right-angled junctions should be avoided. Junctions and bends, when fitted with inspection-covers, are to be preferred.

It is very desirable to provide inspection-chambers along the line of drain, and especially at all sharp curves and junctions, so as to allow the passage of a jointed rod from one to the other, should it become necessary. A set of these rods, making up at least fifty feet in length, with the usual fittings, should always be on hand at a country house. (See Fig. 249, p. 623).

Wherever dummy junctions have been put in, with a view of providing for a future limb of drain, care should be exercised to close up the end of the junction with a proper disc solidly jointed.

It is wise to give a small extra dip whenever a bend or junction occurs in the length of the drain, in order to counteract the effect of friction.

When a diminishing pipe, as it is called—for instance, one taking a nine-

inch drain into a six-inch—the proper tapered pipe, made for the purpose, should always be used. No other treatment will make sound work. As a rule, a large-sized drain should never be taken into a smaller one, but diminishing pipes from large to small will be found convenient when interposing a syphon, say, for instance, at the disconnection-chamber.

It should be a general instruction that syphons, wherever placed, should be a size smaller than the pipes in front of and behind them. For example, if the drain be nine inches in diameter, the syphon should be six inches. This rule may be relaxed in some instances, in the case of six-inch pipes.

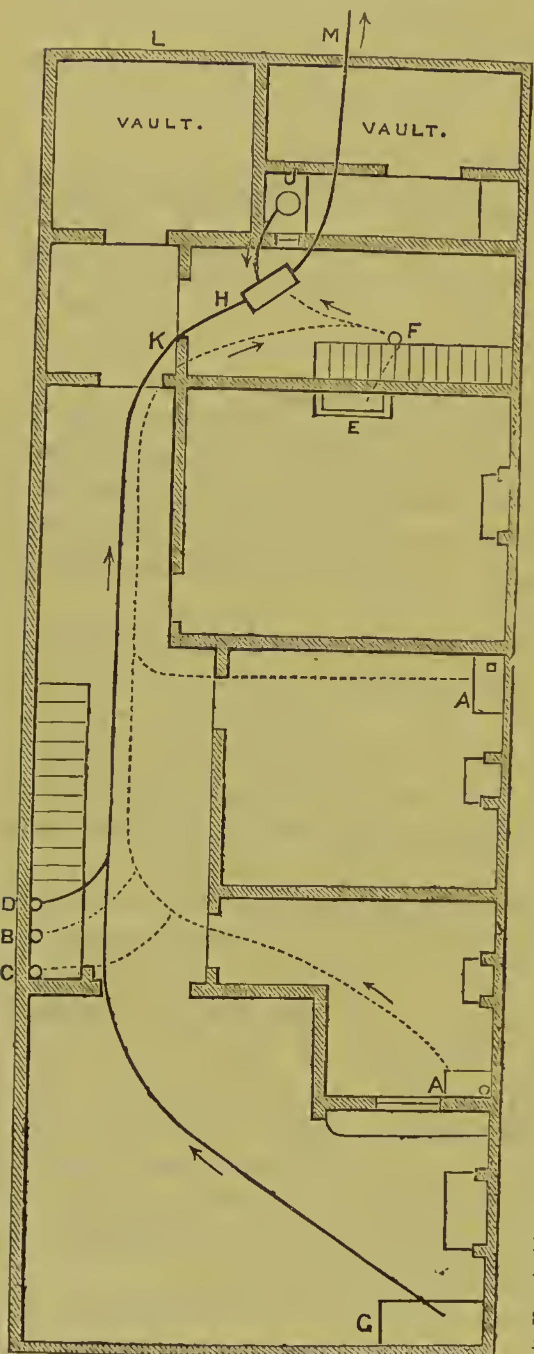

Fig. 277.—Twin Drains.

Entrances into the drain in the floors of basement-rooms should always be avoided, or if they must be provided—as, for instance, beneath the hot water draw-off of a kitchen-jamb or dairy or laundry floor—then such traps should be in connection with another disconnection-trap somewhere in the open air. These traps should be small gully-traps, or lip-traps, and never bell-traps.

It is considered a wise provision to insert a flap-trap at the end of the house-drain where it enters the sewer. Should the outfall of any drain from the house terminate in the open, it should be protected from rats, &c.

In many houses, owing to the want of open spaces at the back part of the house, where the various sewers requiring it could be disconnected in the open air—such as, for instance, sinks and rain-water pipes—it is sometimes found desirable to lay down a twin drain, one removing the closet excreta and perhaps the scullery grease, and the other the cleaner wastes from baths, lavatories, and house-sinks. Fig. 277 shows a house so treated. Here it would be manifestly imprudent to take the waste of the butler's and housekeeper's sinks at A A and E, the rain-water descending at B, and the bath-water descending the pipe at C into the soil-drain, which is marked by the thick line, because all these services would then be in direct communication with the drain. It becomes necessary, therefore, to provide a place where these can empty themselves into a gully

before entering the drain removing the closet-soil. In the house which I sketch, the only available place for disconnection is in the front area, at the gully F; and in such a case as this a twin drain is desirable, laying it alongside the other at its proper level, and raising it up sufficiently high where it must cross the soil drain-pipes. It would not be wise to lay one pipe on the top of the other all along the route; but the cleaner wastes-drain, which is marked by the dotted line, should be laid at a higher level than the soil-drain, and this is almost always possible.

It may here be remarked that the twin drain, removing the bath, sink, and rain-water wastes, should not deliver direct into the disconnection-chamber at H, because that would not be, properly speaking, in the open air, although there would be an inlet of fresh air into the chamber. By causing it to deliver into the area-gully first of all, before it enters the disconnection-chamber at H, a perfect disconnection is achieved.

It will be noticed in this example that the grease and cabbage-water from the scullery sink at G, and the soil descending the soil-pipe D (which pipe is ventilated the full sectional area up to above roof), all enter the disconnection-chamber at H before passing through the vaults to the sewer; and it will be seen, moreover, that the servants' closet at J, situated in one of the vaults, is made to enter the disconnection-chamber as well, so as to give the whole of the house the benefit of the severance from the sewer. In these cases, a ventilating-pipe would almost be required to the end of the drain at G, and the flushing arrangement of the servants' closet at J should be rendered a powerful and automatic one, in order to keep the syphon of the disconnection-chamber thoroughly clean.

It is very desirable that every residence, large or small, should be disconnected from the drain in some of the methods shown in the chapter treating upon disconnection, and an efficient influx of fresh air should be allowed, either by an open horizontal or perpendicular grating, or a mica valve inlet. A corresponding outlet for the air introduced should be provided at the end of each ramification of the drain.

When it becomes necessary to lay down a syphon in a line of drain, the pattern having a pipe rising from the centre of the syphon should always be avoided, and preference given to a pipe which has an access aperture at the beginning of the trap and a raking-pipe beyond.

When laying down the drains, outside the house, in the neighbourhood of trees or a shrubbery, the utmost possible care should be taken with the jointing; in fact, quite as much care as with the drains in and around the house, because the roots of the plants in the search for water will otherwise certainly find their way into the pipes, quickly causing a retardation of the sewage, and finally completely stopping up the drain. Pipes laid under these conditions should be especially well protected by the composition I have described in my former chapter on Drain-pipes and mode of laying same. (See p. 620.)

Pipes which constitute a soil-drain should never be jointed with clay, but with cement. Where, however, they run through perfect clay, this may be allowed; but under no conditions, inside or around the house, should anything but cement jointing be permitted, with the usual rule of surrounding by concrete the pipes laid indoors.

Whenever it is possible to avoid it, drains should never be laid down inside a house, and the deliveries of metal pipes into the earthenware pipes, even when the drains are laid outside, should be made outside the walls.

The site of a house—that is, the space enclosed by the walls of the house—should be under-drained, so as to make certain against any lodgment of subsoil-water, and the floors of the basement afterwards concreted. This subsoil-water should never be led into a soil-drain; neither should the waters of the areas around a house. Where, however, there is no help for this, then these drains should be disconnected from the drain by interposing a suitable gully.

On no occasion should the overflow of any well or rain-water tank be connected directly with a drain. Disconnection is here an imperative necessity.

In re-laying the drains of an old house, where brick drains obtain, the whole of the brickwork should be removed, together with all sodden earth, and fresh gravel, or other cleanly material, thrown in their place, and well rammed down. On no occasion should the bottom of the old brick drain be left in, or even the sides. When removing the latter, and where the brick drain is below the footings of the main walls, care should be taken to shore up or underpin.

When the disconnection-chamber between the house-drain and the sewer must perforce be inside the house, it should be covered with a stone and ring, and the air-inlet brought from the nearest open space; and when the drain is sufficiently deep, and near to an open space, a side entry should be made into it. Wherever possible, however, means should be contrived to bring it outside. For instance, the soil-drain marked by the black line in Fig. 277 formerly ran in a line from K to L, and in order to get the disconnection-chamber out in the open area it was fixed where marked at H, and a new entry into the sewer was effected from M. Sometimes, however, when the sewer is a long distance from the house, it might be advisible to lead the outgo of the chamber at H back to the sewer at L, by way of an easy bend.

Where the size of the house calls for a grease-intercepting chamber, these should be placed outside the house, in an open space, wherever it is possible to do so. If, unfortunately, such a provision must be made inside the house, the chamber should always be ventilated in some manner, and covered with a stone and ring. When iron manhole-flaps are laid down in place of such stones, care should be taken to see that they are absolutely air-tight.

It may be held to be always possible to provide a means of flushing out the drains. For instance, with a small cottage, the rain-water could be caught in a barrel placed above a gulley, and fitted with a standing waste, which could be removed when it became advisable to cleanse the drains. Certain cisterns could be dealt with in a similar manner in the cases of medium-sized houses. For larger establishments, a flushing-chamber, such as shown at Fig. 275, would be used with advantage.

Where the drains of a house or cellar are subjected to tidal influences, or back-water from a pond or river, it would be wise to make use of such a ball-valve as is given at Fig. 274. Care should be taken to obviate any evil due to a compression of the gases in the drain by breaking the connection between the drain and the high-water line, by means of a ventilating-pipe.

Pipes conveying rain-water from the roof should never be made use of for ventilating drains, but should, on the contrary, be disconnected at the foot, and made to deliver in the open air over a proper gully.

Gas and water pipes should not be laid in the same trench, or alongside any drain-pipe, because these small pipes have frequently to be laid bare, and this might endanger the soundness of the drain.

The waste-pipes or overflows from all closet-trays, bath-wastes and safes, lavatories, cisterns and cistern-trays, should always deliver themselves into the open air; the ends of safe-wastes should be fitted with a small copper flap, to prevent the intrusion of cold air.

Soil-pipes should in all cases, whenever possible, be fixed outside the house; and where the architecture demands it, these pipes may be of iron, with properly-made air-tight joints. When they are compelled to remain inside the house, they should be formed of lead. To properly ventilate these pipes, they should be carried up the full diameter. In the case of a ground-floor closet, the pipe may be reduced. All ventilating-pipes of this description should be taken above the eaves, and where there are dormer windows, or ventilated skylights, they should terminate at some height above them. These pipes should not be placed alongside the chimney-stacks, but bent away from them. A safe rule is to terminate the soil-pipe six feet above and four feet distant in position from any window, placing a finial over them, to keep out birds.

Bell-traps should never be used, D traps with caution. The best kind of trap is the syphon, having an access-trap screwed in. It may be taken as a safe rule, that closets should be fitted with lead P traps, and not with those of the conventional D form.

Closets should be confined to one part of the house, and built over each other as much as possible, projecting out from the house. They should never be permitted to remain in the middle of a house: for instance, at a staircase landing opposite bed-rooms, unless there be a shaft from them carried up to the roof, or some other means of efficient ventilation. Whenever possible, fix a fresh-air inlet-tube, with a corresponding outlet at the top of the closet-room. All seats and risers should be so fixed as to come readily apart without the use of the screw-driver.

Pan-closets should never be used in or about a house, and almost any other closet except the hopper closet will serve modern requirements.

Valve-closets having flushing-rims are preferable for use in the best rooms, and wash-out closets for servants' use. No closet should be supplied with flushing-water from a cistern supplying any draw-off tap at any sink, except a disconnection-cistern, with separate ball-cock, be provided overhead the closet.

Slop-closets, for the reception of bed-chamber slops, should be provided in the larger residences where room can be found for them. When they are not provided with an entry into the ventilated soil-pipe, chamber-slops are always thrown down into the water-closet, and the trays underneath are frequently flooded with foul liquids. It is not desirable to place such a slop-closet in a bath-room.

It should be taken as a constant maxim, that no pipe should deliver direct into the drain, except solely the soil-pipe, taking the closet and slop wastes. Everything else, without exception, except there be a grease-collector to the scullery sink, should deliver their contents in the open air over a proper gully. And it is a matter of recommendation to have the sink, bath, and other waste-pipes of that description continued up a convenient distance and left open at the top, so as to get a constant current of air through them.

Where the outfall of the drain is unavoidably into a cesspool, a disconnection-chamber must be placed between the house-drain and such cesspool collection. Cesspools can only be permitted with safety under certain conditions, which will be explained in the chapters headed Treatment of Sewage.

When a disused cesspool has been discovered in or around the house, or when a cesspool lately in use has to be abolished, consequent upon improvements made in the drainage, the whole of the brickwork should be removed, as well as any foul subsoil, and the place filled up with clean ballast. On opening up an old disused and unventilated cesspool, care should be taken not to break into it with any light near, as violent explosions are very common in such cases.

CHAPTER LXVII.

SEWAGE-DISPOSAL.

Ancient Methods of Sewage—Cesspools—The Water-closet System—Irrigation—Subsoil-irrigation.

Having brought the reader up to the disconnection-chamber, which separates, or should separate, the house-drain from the outfall, it now becomes necessary to deal with the outfall itself; but, before doing so, a short review of the various methods of dealing with the sewage would be not out of place.

Where communities, large or small, are gathered together, whether it be in towns, villages, mansions, farms, groups of cottages, or in public institutions, there of necessity the question of sewage-disposal forces itself on the attention. From very remote times attention was given to this question, and laws laid down for guidance in sanitary matters which exist to this day, and may be considered as a monument of wisdom. Coming down to the Roman period, we find that works of sanitation were highly considered, and that great sewers, such as the Cloaca Maxima, were inaugurated even by emperors. There can hardly be any doubt that a people who were so careful about the greater works would also be careful in their lesser works of the drainage of individual houses; and we know, from the remains even in this country, how the Roman villa was provided with special drainage-arrangements. In mediæval times we find, perhaps, one of the darkest periods of sanitation, and this state was maintained down to a recent period, and pertains even now in some countries. It were foreign, however, to the scope of this article to inquire into the method, or rather the want of method, in disposing of sewage from communities at any special period.

The state of the sewage-question, regarded either for the single house or blocks of houses, was, down to a late period, in a most primitive condition. The slop-waters were conveyed by wide drains, mostly square, and leading to the nearest watercourse, and the old privy-system served for the excremental matters.

The history of such a river as the Fleet, or River of Wells, as it was called, from its being fed by so many wells in the neighbourhood of Clerkenwell, gives a very good idea of the early sewerage-disposal for a community. This once bright and sparkling stream, which had served as a water-supply, was gradually the carrier of all the sewage for the houses which grew up along its course.

This befouling of the watercourse drew attention at a very early date, for we learn that the monks of Whitefriars petitioned the king in A.D. 1290 that some measure might be taken to restore the stream to its pristine condition. This, however, was not done; and gradually it became worse, and more of a sewage-carrier than ever, until the time came when it was so abominable, owing to the sewage-waters being taken into it, and from the conveniences overhanging the river, that it was gradually disused for navigation, and at a still later date was arched over and converted into a sewer, which it still remains even to this day. This sewage-nuisance and the fouling of the Thames at London was further increased

with the enormous growth of the population, and it was found necessary to carry out the gigantic work which at present carries the sewage from London down towards the mouth of the river, at Barking on the north side and Crossness on the south side. This disposal, although it has left London in a somewhat better state, and purified the river, has nevertheless given rise for serious cause of inquiry, and we may predict that at no very distant date the sewage-question will have further to be considered.

The invention and introduction of the water-closet apparatus, at the beginning of this century, marked a distinct epoch in the history of sanitation. These contrivances brought in their train much danger, being used in connection, not with sewers as at present, but in the great majority of cases being conducted into cesspools within the house. Many of these cesspools are to be found in the older houses of London in the basement, and oftentimes under the kitchen floor. The overflow from these cesspools was allowed to go into the public sewers, and the object of the cesspool was to retain the solid portion. The custom was that when one cesspool was full another should be made, and thus a great many of these receptacles are discovered in one house.

The condition of the metropolis was no doubt very unsatisfactory from the existence of these cesspools, and the consequent fouling of the wells from which water was in a great measure drawn. The occasional appearance of cholera also pointed to a great sanitary defect, but it was not until about the year 1850 that the Public Health Board revealed by its labours some of the salient points of the sewerage-system of the towns and villages. A great and important step was rendered possible by the advocacy of glazed earthenware drain-pipes, which were advocated as sewer-ducts, especially by Mr. E. Chadwick in 1840.

The introduction of the water-closet apparatus at the beginning of the present century caused the question of house-drainage to become considerably altered. Many difficulties were by this introduction made evident, such as the foul gas brought into the house through soil-pipes, and the greater bulk of sewage to be dealt with on account of the water used for flushing such apparatus. Cesspools under this altered condition became rapidly filled to overflowing, and it was necessary to construct new cesspools, as fast as the other ones were filled. Porous strata, such as the chalk districts, the new red sandstone districts, and the oolite districts, furnished special facilities for such a disposal of water-carried sewage, and in many towns and districts this is the principal mode of disposal obtaining even to this time. In some chalk districts—notably in the Isle of Thanet—this disposal of sewage has been the cause of pollution to the water-supply of the district, the supply being taken from wells sunk into the chalk.

Those persons who have been engaged in examining the sanitary conditions of towns and villages, and even of detached homesteads, in this country, know what a fearful state of things exists respecting sanitary arrangements, where in many cases the house-drains and overflow of cesspools are carried by unsuitable conduits to the nearest brook or watercourse, causing in the summer months an intolerable nuisance. Cases also come under notice where homesteads, mansions, and towns are situated on elevated positions, with beautiful surrounding district, where everything would seem favourable for the disposal of sewage; but nevertheless, owing to want of careful consideration in these matters, they are the homes of pestilence,

instead of health, as they should be by their natural position. The cesspool from the dwelling often occurs in dangerous proximity to the well sunk for the water-supply for its community, the cesspool in many cases leaking through into the well whence drinking-water is obtained. We know of a case where the current of the underground water striking around the cesspools of the house, on its way to the well used for the water-supply of this house, gave rise to a serious outbreak of typhoid fever, showing the necessity of either doing away with the cesspool-system in this particular case, or of adopting a very careful position for such cesspools.

The Rivers' Pollution Prevention Act, 1876, provides that no rivers or streams shall be polluted through the admission of crude sewage, even from the existing sewers. The question then arises, how are we to deal with the sewage of towns, villages, and country mansions in a manner so as to be inoffensive?—and numberless plans have been suggested for dealing with this question. We have schemes for precipitation, filtration, irrigation, and numbers of others; and it has often been stated that sewage can be dealt with so as to produce a profit to the community. Experience, however, has shown that this is entirely fallacious; and we have at last come to the conclusion that sewage must be got rid of from our habitations and towns at once, the cost being only of secondary consideration. Sewage-farms have been in operation for a number of years, but few have been able to show any profit. Sewage applied to the land in an efficient manner is purified, and deposits its polluting ingredients in the earth; and the effluent water may be passed into natural watercourses. The additional volume caused by the admission of rain-water and subsoil-water into the sewers has caused a great difficulty in dealing with the question, especially where pumping has to be resorted to. The most successful cases of sewage-irrigation have been those on what is called the "separate system," where the quantity of sewage to be dealt with remains a known quantity. The original idea of admitting rainfall into sewers was to flush and keep clean such sewers; but experience has shown that proper-sized sewers, laid at proper flushing gradients, are best, and that distinct methods of flushing must be adopted at the head of all drains and sewers.

The separate system provides a distinct system of drains for the surface-waters and for the sewage-water proper, and the work of the engineer and sewage-farmer is thereby brought within control. In this system, the sewage goes to the land, and the surface-water to the streams and rivers. Subsoil-drains have been added in many town drainage-systems, and around many mansions, with marked effects for good. Cellars and areas, which were formerly flooded in times of rain, have been rendered dry, and the houses thereby improved.

IRRIGATION.

We shall have occasion to consider more especially the question of dealing with sewage by irrigation—either surface-irrigation or by subsoil-irrigation. It has been shown by experience that sewage can be satisfactorily purified by passing it through the soil with a sufficient depth to act as a filter. In many places sewage has been dealt with by surface-action only, the growing vegetation sufficiently purifying the sewage-waters entering at the outfall. We shall proceed to describe, as much in detail as possible, how the sewage-farm should be formed; and we may

here remark that whether it be sewage from the town, or village, or mansion, the system is essentially the same, the only difference being in the size of works necessary to be carried out.

Various systems of laying out the land for sewage-irrigation have been adopted, and are known generally as the Ridge and Furrow system, the Catch-water system, and the Pan and Gutter system. In the Ridge and Furrow system the land is divided into ridges and furrows, the tops of the ridges running square with the main carriers. In the Catch-water system the sewage is taken in carriers along contour lines, the sewage running along the higher contour carrier gradually fills and overflows the lip of the carrier. In other cases the sewage is turned at certain points into the lower contour carriers, and so diverted to the portion of land required to be treated with the sewage. The carriers may be constructed either of concrete or earthenware half-pipes, and in some cases the sewage may be taken direct into carriers formed in the soil itself, merely turfing the lip of the carrier. The last plan has been found to succeed very well in some places, and has the advantage that the land may be ploughed up in any direction without fear of disturbing carriers of more permanent construction.

A very important matter in most irrigation-schemes, especially where the subsoil water-line is high, is the question of under-drainage. These under-drains are usually laid at about a depth of four feet from the surface, in such a way as to divide the land into about equal areas. In all systems of under-drainage we have arterial drains and cross drains laid in parallel lines. The subsidiary drains are laid with agricultural pipes of two inches in diameter, and the arterial drains may be of any requisite size. Proper inspection-wells are also constructed on many points, so as to inspect from time to time the run of water. The land most suitable for irrigation is that with a gentle slope, and the soil most suitable is of a light, open nature. Impervious lands cannot be treated with large quantities of sewage without most careful attention to the question of under-drainage, for although sewage is purified to a large extent by surface-action on impervious soils, yet in winter-time it does not seem that the mere passing sewage over the land causes the desired purification. To manage sewage-farms with success it is found advisable to have a piece of fallow land, so that sewage may be turned on to it sometimes when the other lands have been fully dosed. Perhaps the most difficult point requiring attention is to deal with the sewage-sludge from the tanks in a manner which shall be inoffensive, and various means have been suggested for accomplishing this purpose. On a small farm, perhaps, the readiest way of dealing with this sludge is to dress a portion of land with it which does not readily come under the irrigation on account of the level. It may, in many instances, be found necessary to disinfect the sewage-sludge and the tank which is being emptied. In some places it has been found advisable to cover the sewage-tanks with an open louvred roof, to avoid any nuisance arising from them; but in the country districts the tanks are generally left open.

That sewage-farms and irrigated lands are not injurious to the health of the neighbourhood adjoining has been abundantly proved. Perhaps no better illustration could be given on a large scale than at the Beddington Farm, Croydon; and it is not too much to say that the value of manurial ingredients in sewage can only be utilised effectually, either by broad irrigation or irrigation combined with

intermittent downward filtration. Irrigation has been carried on for the last two hundred years at the Craigentenny Meadows, near Edinburgh, and the land there is as fit to receive sewage at the present time as it was at first. We may also refer to the marvellous results produced near Paris, where a barren and unfruitful waste has been turned into a vast garden, producing flowers and fruit for the Paris markets. In order to make a sewage-farm workable and profitable, storm-waters and subsoil-waters should be kept out of sewerage-systems. We thus have a known quantity of sewage to deal with, instead of being flooded in times of rain; and there is the further advantage of the sewage being more concentrated.

SUBSOIL-IRRIGATION.

The disposal of liquid sewage by subsoil-irrigation will recommend itself in many instances, owing to the peculiar facilities it affords for disposing of sewage-matter without nuisance. There are many cases where open irrigation in close contiguity to mansions or dwellings might be exceedingly objectionable, and in such cases subsoil-irrigation appears to supply a means of dealing with a very difficult question. Subsoil-irrigation came prominently forward in the attempt to deal with the difficulty of slop-nuisance. By the term "slop-nuisance," we mean the whole liquid refuse of the household, including sink-water, slop-water, laundry-water, &c. The dry-earth system, as devised by the Rev. Henry Moule, M.A., vicar of Fordington, Dorsetshire, dealt successfully with the excrement or solid part of the sewage-difficulty, and this dry-earth system will be referred to in another section. Among the attempts at dealing with the slop-nuisance arising from cottages, we may mention one at Holton, Buckinghamshire, where the slops are conducted by a drain to a small water-tight receptacle in the garden, and from this receptacle they are ladled from time to time for distribution over a garden. The cottages are provided with earth-closets, and each cottage has attached to it a small piece of garden-ground. It is found that the manure from the earth-closets and that from the slop-disposal can be all utilised on the garden-plots.

At the cottages of the Industrial Aid Society at Hereford, sub-irrigation was used for the disposal of slop-water in the following manner. Sub-irrigation drains were laid with small catch-pits at intervals; it was found that the slop-water did not penetrate to any distance into the drains; the porous, loamy soil readily absorbed the liquid. The Rev. Henry Moule has carried on some experiments at his house for the disposal of the liquid refuse of the household in the following way. The refuse flows to a catch-pit in the garden, and has an overflow to a sub-irrigation drain; the garden is cultivated by alternate cropping; fresh slops ladled from the catch-pit are distributed to the garden daily, being the only manure used. Mr. Moule is of opinion that the liquid refuse of a family of seventeen or twenty persons can be profitably used on twenty-five perches of garden, as many as three or four crops being grown yearly.

Later experience has proved it to be possible to deal with the whole of the sewage-matter from a community, including not only the slop-water but the excremental matter of water-carried sewage, by the sub-irrigation principle.

The method of sub-irrigation as applied to groups of cottages, or mansions, or homesteads, received great impetus by the invention of the flush-tank by Mr. Rogers

Field. The chief difficulty of sub-irrigation by gravitation from the ordinary flow was, that no great quantity could be delivered at a time, but small dribblets were discharged into the sub-irrigation drains, and never found their way to any distance along such drains, so that it will readily be seen that only a very small patch of the ground near the discharge of the liquid received any great portion of it, added to which the underground drains became rapidly choked up. By the introduction, however, of the flush-tank, it became possible to hold up the small dribblets in a tank containing, say thirty gallons, and by means of a self-acting syphon to discharge the whole contents instantaneously, thus causing a rush of liquid along the subsoil-drains for a considerable distance.

CHAPTER LXVIII.

SEWAGE.

Old-fashioned Cesspools—Restrictions regarding their Adoption, and Way to Deal with them—Interception of Solids—Overflows—Flush-tank—Sub-irrigation on a Small Scale explained, with Examples—Large-sized Flush-tanks, with Strainers—Osier-bed Treatment of Sewage—Examples of Sub-irrigation.

There can be no doubt that what are now termed cesspools have existed from the earliest times, and were used for the collection of liquid wastes long before the introduction of the water-closet. When the latter appeared upon the scene, the cesspool became an absolute necessity in very many cases, and the practice of making use of cesspools has continued up to the present day, to the great detriment of health.

Very often, before the house was built, the site of the cesspool was previously fixed upon, as being the most important matter. In choosing a locality for a house preference was given to a sloping bank, which would allow of an overflow into some running stream, quite regardless of the pollution of the water. But it is not uncommon to find cases where the house was built first, and, for want of a suitable fall, the cesspool dug out inside the house. This was the case especially in large mansions with ample cellarage-room, and I have discovered and removed as many as eighteen cesspools in one mansion. The rule seems to have been that, when one was full, another must be provided. Generally, these clustered cesspools communicated with each other, especially when they were grouped around the foot of a soil-pipe.

Without doubt, the earliest form of a cesspool was simply an excavation in the earth, where the liquids were left to soak away, and the solids to disintegrate. Cesspools of this description are still dug every day, even now, in geological strata permitting of the ready absorption and dispersion of the wastes. I have no doubt that hundreds are being dug at this very moment in the chalk formation alone. It is a matter of notoriety that the cesspools in the chalk are to be accounted the best, inasmuch as the liquids drain readily away, and the solids speedily disappear. And so much stress is laid upon the adaptability of the chalk for cesspool purposes, that a rule is generally laid down to the effect that these cesspools are not to be cleaned out, inasmuch as when once the sides are touched or scraped, the fissures through which the liquids escaped become filled up, thus transforming the cesspool which gave no trouble, into one which required to be periodically cleaned out.

When experience had proved that it became dangerous to deal with a hole merely dug in the earth, on account of the consequent fouling of the surrounding subsoil, which formed the water-collecting medium for the drinking-water of the house, the cesspool was then built around in such a manner as to render it water-tight. Sometimes overflows were provided, and where these were not possible, the liquids were baled or pumped out as occasion required. It cannot be doubted that the value of such sewage was appreciated, and that in farm-houses the rule was to throw it upon the land. And, doubtless, this liquid manure, derived from all sources,

was made use of even in mansions, at the gardens and other places, though with less persistency, inasmuch as the sewage was too raw and heating for the gardener's ordinary uses. The rule was to provide an overflow to the cesspool of large mansions, and lead it to the nearest stream, river, or pond. Cesspools of this description, untouched for the last fifty years, may be found in and around thousands of our country houses, their very whereabouts being unknown to the oldest resident. Surmising the existence of these cesspools, I have spent whole days before I discovered them. On one occasion I laid bare five of them, just outside the walls of a residence, and they averaged forty feet in depth! No one had the slightest knowledge of their existence, and believed that the whole of the drainage ran into a lake below.

It is hardly credible, but I can assure the reader it is so, that sometimes when a well in the vicinity of the house has been poisoned by sewage, in order to lengthen the periods between cesspool emptyings, the old well has been converted into a cesspool, and a new one dug! I knew a cesspool of this description about ninety feet deep, and the inlet into it from the house was seventeen feet from the surface. It was situated in the chalk, and had never required to be cleaned out. It was ventilated by a pipe up the side of the house. On one occasion I came across a large residence which had neither drain nor cesspool, and everything found its way in the open air to the nearest rock crevice, and beyond that no one knew what became of the liquid sewage.

It is a very safe thing to say that a cesspool collection is improper, and that the evils connected with it are many and serious, unless the utmost precautions be taken. The usual practice has been, and is yet, to build a water-tight cesspool, taking the overflow into the nearest ditch, sometimes only providing a ventilating-pipe, and almost invariably taking the pipes from the house direct into it. Sometimes a flap-trap was placed at the end of the pipe inside the cesspool, but seldom was any disconnection practised between the tank and the house. In consequence of this, the broken well-traps in the floors, the untrapped sinks, and the closets, especially when the handles were lifted, and the neighbourhood of all these services in the early morning, evinced the presence of the foul air generated in the cesspool; and to make matters worse, the drains were very often far from water-tight, and were in most places not free from deposits.

Under conditions such as these, a cesspool collection is a positive pest, even in the country; but when it occurs in a town, the amount of danger is incalculable. There are in London yet, thousands of houses which drain into cesspools, and have only the overflows taken into the sewer. As a matter of course all these cesspools should be abolished, and when a block of old houses is pulled down in a city like London, the whole site should be ploughed up in a search for these old receptacles, as otherwise some of them may come to be left inside the walls of the new house.

The question arises, can cesspools be made use of under any circumstances?—and in reply I would venture to say that no condition of things can justify the building of a cesspool upon the old-fashioned system. It can only be necessary to provide one at all when there is no other way of dealing with the sewage, and these conditions are rare. When a cesspool has to be built, it should be at the farthest possible distance from the house, the house-drain disconnected from it by some one of the kinds of disconnection previously explained, the drain between the discon-

nection-chamber and the cesspool frequently ventilated, as well as the cesspool itself, an inlet-trap placed just before the entrance into the cesspool, and every other precaution taken to prevent the passage of foul air from the cesspool to the house.

When it is incumbent upon the owner of a residence to have recourse to cesspool outfall, he should never preferably make choice of any arrangement which permits of the carriage of both solids and liquids to the cesspool. It is bad enough to have to lead the liquid wastes to the tank; the solids should be intercepted on their way to the cesspool by any suitable arrangement of depositing-platform, and these solids should be collected daily and covered with earth for future garden purposes. The nearer the house this can be done, convenient to some privacy, the better the arrangement will work. This system of intercepting solids on their way to the cesspool is fast becoming generally practised at country residences. I have seen examples which have been in regular working condition for some years, and given every satisfaction.

The advantages connected with this system of solids-interception on their way to the cesspool are many; chief among them is the fact that the cesspool is freed from a great deal of deposit, thus rendering it easier to deal with the manure upon the land, and also lessening the smells generated in the cesspool. This practice also gives the excrementitious products direct to the earth, with which they become very speedily incorporated. The value of the earth thus enriched is especially well known to the gardener. A sketch of a suitable strainer, or solids-intercepting chamber, is given at Fig. 278. Here the strainer A is of thick wire, in an iron frame, and is made movable. The chamber has a concreted bottom and brick sides, and the rounded bed of the bottom is smoothly cemented. In this pattern of straining-chamber, the solids can be scooped out and carried away. Preferably, where there is a sufficient fall, they are made to collect upon a movable tray; the whole is covered by a hinged wooden lid, as shown at B.

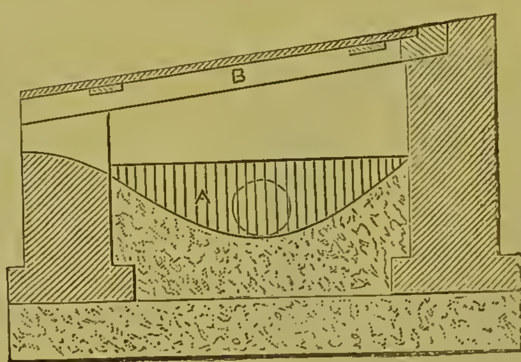

Fig. 278.—Solids-strainer.

It very often happens that a cesspool is obliged to be built in a place which will not admit the carrying away of an overflow from it. And as it is full of risk to build a cesspool without making it water-tight, in such cases as these, the tank would require to be periodically emptied by means of a pump, and the sewage carted away to where it could be used upon the land. When there is a stream in the neighbourhood of a cesspool, the overflow of the latter should not be taken into the stream or ditch, although this is very frequently done. Sometimes the overflow of a cesspool can be provided for by causing it to deliver itself into a series of agricultural pipes, arranged around the cesspool, and placed a foot or so underground, with open joints. I have seen this kind of treatment of the overflow work tolerably well in the field and garden; if the drain-pipes fill up, they can be easily taken up and re-laid, and in another direction if need be. The cesspool itself should always be ventilated, the amount of ventilation depending upon its capacity for storage.

If the cesspool-system, where its adoption becomes unavoidable, is treated as indicated above, the nuisance of a cesspool at all will be reduced to a minimum. But it should be taken for granted that a delivery of the drainage of a house into a cesspool should only be resorted to when no other scheme can be devised; and before a cesspool is decided upon, a competent opinion should be obtained as to whether some method of irrigation, for instance, could not be arranged in its place. Where a cesspool must be adopted, it should be kept as free as possible from the inflow of rain and surface waters. As much as possible also, the earth or ash closet system should be adopted outside the house, so as not to fill the cesspool too quickly. This last remark, however, would only refer to houses with but little land, and not where there is abundant facility for throwing the sewage upon the land.

In very many places where cesspools were in use, these are fast being supplanted by the system of sub-irrigation, which consists in discharging the liquid sewage into pipes laid underground, with a view to its being absorbed by the earth to the benefit of the vegetation overhead. It is not, however, every kind of soil that will permit of the disposal of the sewage in this way, and before it is resorted to, the nature of the ground should be carefully examined by some expert; as, where the land is not suited, and cannot well be made suitable, for sub-irrigation, something else must be resorted to.

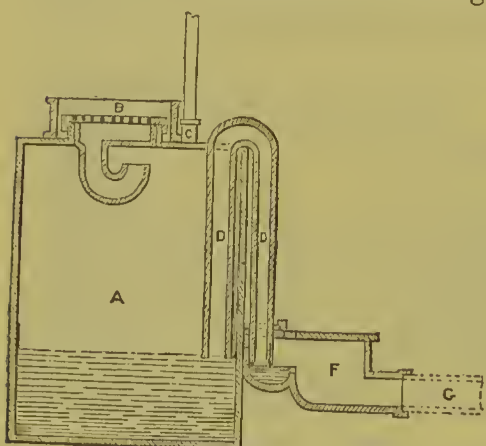

Fig. 279.—Field's Flush-tank.

A section of Mr. Field's improved flush-tank, suitable for the collection of liquid slops for the carrying out of sub-irrigation, is drawn at Fig. 279. It consists of a cylindrical iron tank, A, with a trapped inlet, B, which also forms a movable cover to give access to the inside of the tank. The pipe from the sink discharges over the grating of the inlet, as shown on the figure. C is a socket for ventilating-pipe, D the syphon, and F what is called the "discharging-trough," consisting of a small chamber, made to turn round so that its mouth may be set in the direction that is required for connecting it with the line of outlet-pipes, G, and provided with a movable cover for access to the mouth of the syphon. This "discharging-trough" is an important feature of the tank, as it is of a peculiar shape, which, by checking the outflow of the liquid from the mouth of the syphon, enables a smaller quantity of liquid flowing into the tank to fill the bend of the syphon and set it fully in motion. So completely does this effect its purpose, that a hand-bowl full of water thrown down the sink, fitted with an ordinary bell-trap and pipe, will set the syphon in action when the tank is once full.

The sink-pipe discharges over the grating of the trapped inlet, B, outside the house, so that the connection between the drains and the house is completely broken, and any entry of foul air is impossible. The top of the tank is completely closed by means of the water-joint round the cover, and the cover is readily removed when required. The inlet, moreover, forms a basin, which may be used for throwing down slops outside the house. This is specially advantageous when earth-closets are used, as it enables the bed-room slops to be kept out of the earth-closets.

A very convenient form of this flush-tank is now made in earthenware, and, instead of standing erect, it takes an elongated horizontal form, and is more handy to manage. The automatic delivery of its contents is, however, equally well provided for.

A very good example of the sub-irrigation system, as carried out on a small scale, in the case of two cottages at Shenfield, in Essex, is given at Fig. 280. The flush-tanks used there were among the first devised by Mr. Field, and received the slop-waters only. And it may be here remarked that it is usual to lay a portion of water-tight drain from the dwelling away towards the plot where sub-irrigation is practised, in order to avoid contamination to any wells from which water is derived for drinking-purposes.

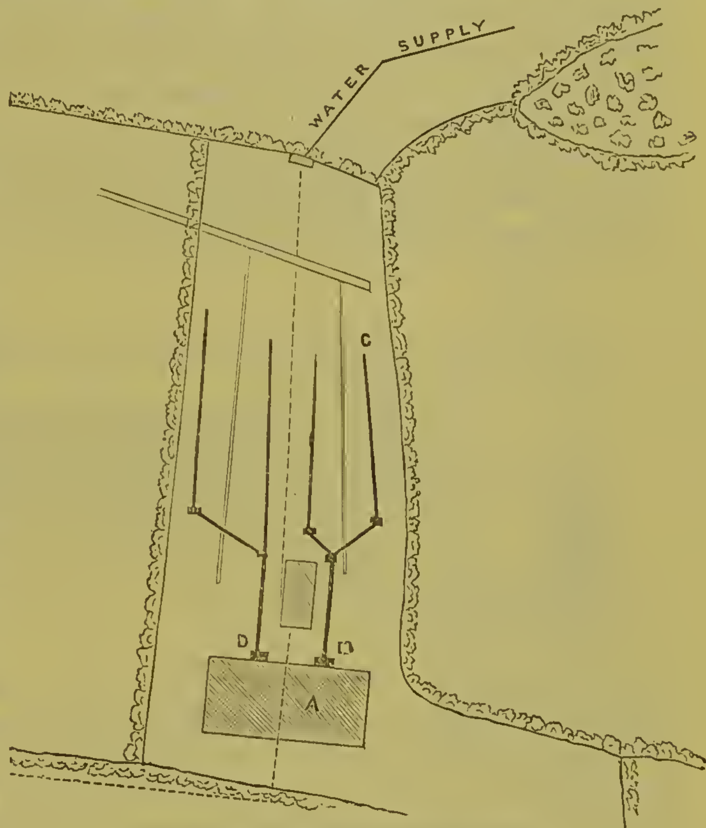

Fig. 280.—Sub-irrigation at Shenfield.

This example of sub-irrigation cannot be better described than as under: A representing the cottages, C the irrigated ground, and D the flush-tanks. The water-tight drains are represented by the thick black lines from the tanks, the sub-irrigation drain (1 foot deep) by the thinner black lines, the land-drains (4 ft. deep) by the double lines between the latter, and the inspection-wells by the square black dots. The total area of land and building is 1 rood 9 perches; the area of land irrigated about 14 perches.

In this case it was found necessary to under-drain the gardens, owing to the nature of the soil, which was a mild clay. Unfortunately, the sub-irrigation and land-drains were found to be too near together, so that the sewage occasionally penetrated direct to the land-drains without sufficient passage through the soil to purify it, and the sub-irrigation drains had eventually to be taken up and re-laid. The position of the land-drain was, however, such that it was impossible to lay the sub-irrigation drains at a proper distance from them. Notwithstanding this drawback, the sewage was under ordinary circumstances entirely absorbed by the soil and vegetation, the intermittent action of the syphon greatly assisting this result, by giving full opportunity for the purification of the sewage, on the principle of "intermittent downward filtration." The sub-irrigation pipes were intended to be taken up and cleared annually; but they were actually left undisturbed for nearly three years without any practical inconvenience. On being taken up, they were found to be partially choked, but still able to allow the sewage to escape into the soil very rapidly. The sub-irrigation has now been in action for a number of years, and, on

the whole, is a decided success. The deposit in the tank is willingly cleared out every two or three months by the tenants, who like to have it for use in the garden; and the cost of clearing the sub-irrigation drains is only a few shillings annually, as they can so readily be taken up and relaid in the permanent bed.

The system above described has been further elaborated for dealing with the liquid house-refuse of villages and towns, and a tank was designed called an automatic sewage-meter, constructed on the same principle as the flush-tank. This meter-tank was built in brickwork in two separate compartments, so that one compartment could be used while the other is being cleaned out. A meter of this kind was erected near Leatherhead (Surrey), and dealt with the sewage of a hamlet of thirteen houses, including the mansion and the farm homestead, with a population of about 145 people. The drainage-scheme was carried out by Mr. Bailey Denton, and dealt with the liquid house-refuse of the homestead, the drainage of the farm-buildings, and about four water-closets. The common privy was retained for the cottages, and was made a water-tight receptacle, the contents of which were re-

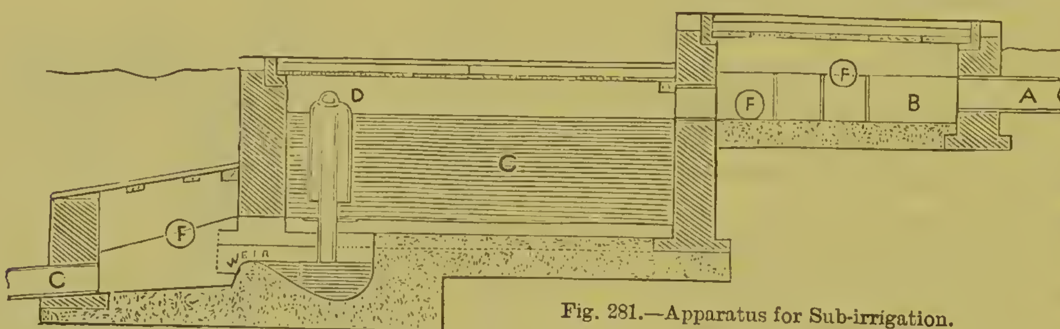

Fig. 281.—Apparatus for Sub-irrigation.

moved monthly for use on the gardens. There was also the drainage of cattle-sheds, stables, and piggeries. The capacity of the tank was 500 gallons, and it filled and discharged three times in two days; the several discharges were directed on different portions of a plot of ground prepared for the purpose. The arrangements as carried out at Eastwick may be regarded as complete and satisfactory, and it has been calculated that about five per cent. on the outlay of the works is realised. The irrigated land, in this instance, is in close contiguity to the mansion, but no nuisance is experienced from it. Previous to these works being carried out, the slops from the cottages and mansion found their way into the neighbouring ditches, and decomposed there, causing considerable nuisance, especially in the summer-time.

I have already described and illustrated at Fig. 275 a large flushing-tank, having an annular syphon fixed in it, by means of which, when water has risen up to a certain height, the whole of its contents—say 300 gallons, for example—are discharged automatically. This syphon is of the utmost value in irrigation.

A section of a tank for this purpose is shown at Fig. 281, with the chamber where the solids are strained back, as explained at Fig. 278.

But it is not always necessary to have so many iron strainers. The sewage from the house enters at A, is strained at B, the liquid portion reaching the tanks at C; and when the sewage has reached the maximum water-level, the syphon D is actuated, and the sewage discharges into the trough, and passes over the weir to the outfall.

A by-wash and overflow-drain is led around the tank at the back, and these pipes are shown at F.

As can easily be understood, a tank of this description would never be relied upon to deliver the sewage of a house to a piece of land unless the sewage was carefully strained and the solids removed. The full advantages of having a periodical discharge, and the fact that the solid excrement is properly dealt with, by being collected and covered with earth until it becomes invisible, can hardly be realised until such an arrangement as I have given is examined in detail where at work. Sewage which has been strained in such a manner as this, and collected in an intermittingly-discharging tank, which gives the ground to be treated

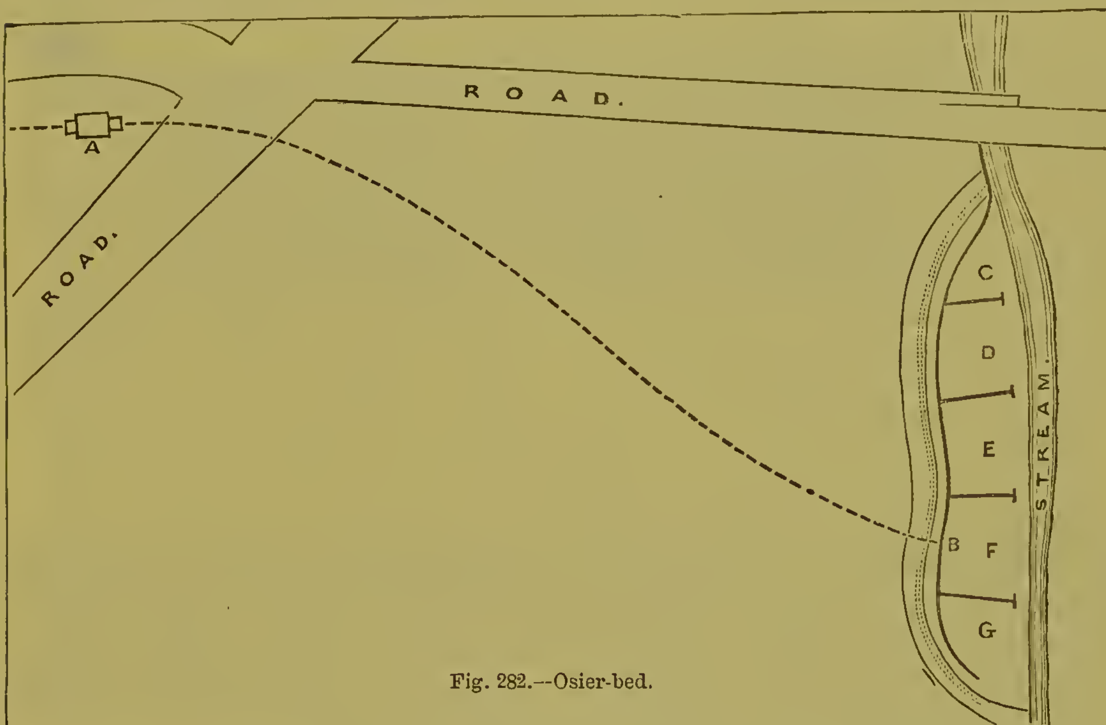

Fig. 282.—Osier-bed.

some time to rest before it discharges again, can be used to great advantage in connection with an osier-bed. Fig. 282 gives an example of this kind. The straining-chamber and tank which receives the sewage from the mansion is situated at A, and the discharge on to the osier-bed is at B. The thick black line represents the trench which receives the sewage, and at will this sewage can be confined to any of the plots marked by the letters C to G inclusive. The mansion is fitted up with water-closets only, and the whole of the sewage finds its way to the tank at A. The area covered by the osier-bed is only about a quarter of an acre, and the nature of the land is such as not to require subsoil-drains. Sufficient drainage for the effluent water is procured by a wide trench, as shown by the double dotted line, gradually deepening to where the purified sewage joins the stream.

Where an osier-bed is properly dealt with, the greed with which the plants lick up sewage is astonishing, and the water discharged from them is remarkably pure; but everything depends upon the suitability of the land, and as to whether the beds require underground drainage. Where these points have not been well considered, the site will become water-logged, and probably prove a nuisance. One

thing in favour of the establishment of an osier-bed, where it will suit, is that it yields, or ought to yield, periodically, a tolerable profit.

The following plan (Fig. 283), scale 66 feet to an inch, shows a plot laid out for subsoil-irrigation, where the strong continuous lines indicate the position and run of the water-tight drains. The subsoil-drains are of agricultural tiles generally, 2 to 3

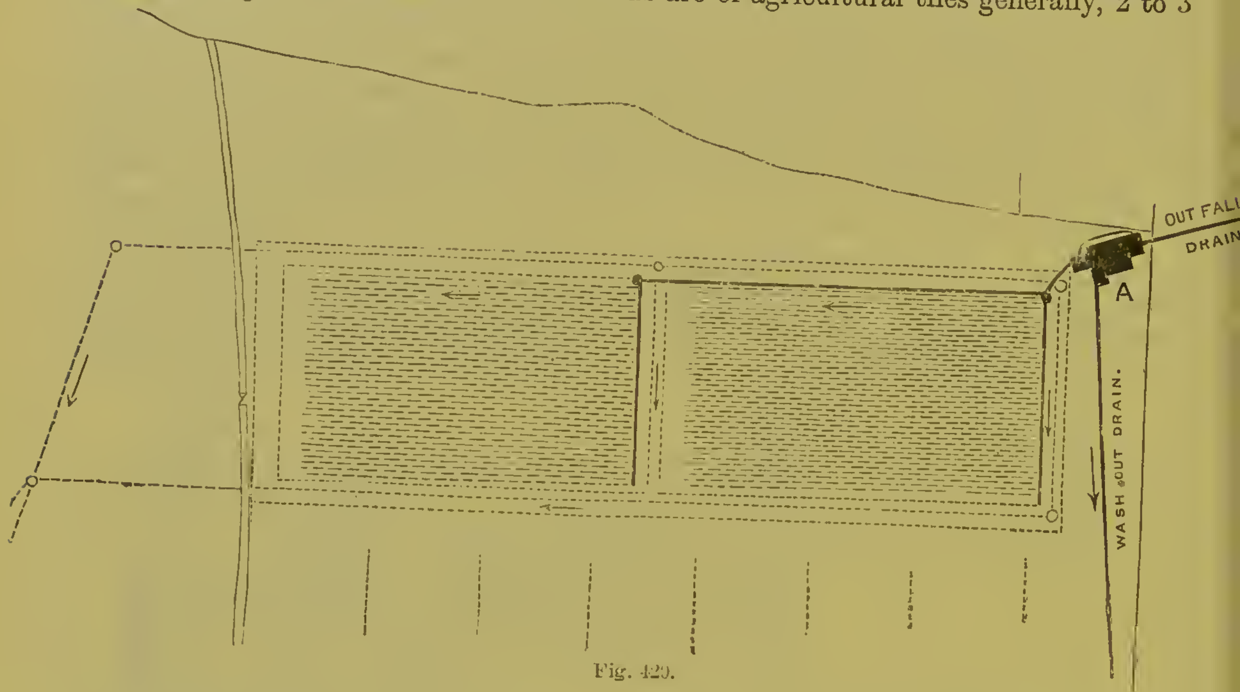

Fig. 429.

inches diameter. The subsoil-drains are laid about 2 feet below the surface, on a bed of half-round tiles. The sewage from the outfall drain is delivered into a brick tank at the point marked A upon the plan, which is of sufficient capacity to hold, say, one day's flow. The tank is fitted with a self-acting syphon, which discharges the contents of the tank suddenly, and causes a flow of the sewage through the water-tight drains, and thence into the minor drains. These drains, being laid open-jointed, allow the sewage to percolate into the ground.

CHAPTER LXIX.

SEWAGE-TREATMENT.

Sewage—Surface-treatment—Tanks for Irrigation—The Flat-bed System—Special Irrigating Appliances, Pipes, Valves, &c.—The Contour or Catchwater System—Osier-bed Treatment—Pane and Gutter, or Ridge and Furrow System—Combined Treatments—Sewage Cropping—Intermittent Downward Filtration and Sub-Irrigation—Examples of Same—Delivery into the Sea—Precipitation.

It now becomes necessary for me to give some examples of the various methods of dealing with the sewage which accrues from the larger establishments; and I will do this as briefly as possible, since all I need do is to simply furnish the reader with an idea of some, at least, of the many methods which are employed for the disposal of sewage other than by the storing of it in cesspools.

First of all let us define what sewage is. Sewage is water holding in suspension and solution ingredients which do not belong to it as water, which render it objectionable to sight and smell, injurious to health, and unfit for the domestic uses of man. Town or house sewage is water brought to this condition by the addition of human excreta from water-closets and urinals, sink-washings, the washings of the surfaces of streets and yards, and the refuse from trades and manufactures.

To remove from this foul water the substances which give it the title of sewage; to take from it the smell, colour, turbidity; to destroy the germs of disease, bred or discharged into sewers, and to bring it back as nearly as may be to the original state of pure water; this is the constituted end of all sewage processes.

Accumulate sewage is, under ordinary circumstances, a bluish-grey turbid liquid, and gives off, in coldest weather, when fresh, a smell which more resembles that of stale cabbage-water than that which might perhaps be expected; but in warm weather, or where it is long in reaching its outfall, to use a homely illustration, the still more offensive smell of rotten eggs is added. This smell is more or less apparent according to the degree of concentration, or to the degree to which putrefactive decomposition has proceeded, and the offensive combination is now generally known under the term of sewer-air or sewer-gas.

Sewage when allowed to stand does not become clear; the grosser portions of its suspended matter are indeed deposited by degrees, and in this way a certain improvement is brought about; but from its slimy, glutinous nature it is difficult, if not impossible, to get anything like a clear liquid by subsidence. The same is practically true of the ordinary artificial filtration of sewage; for although it is possible to filter sewage, the pores of the sand, earth, or other filtering-material employed, soon become choked; and all attempts to thoroughly *filter* sewage on a large scale have hitherto resulted in failure.

The suspended matter of sewage is partly of an animal nature; consequently, by exposure to the air at any ordinary temperature it is liable not only to suffer putrefaction itself, but to induce it in other substances of a more inert character. The putrefactive change occurs most readily when the sediment is exposed to the air, as when the deposit found in sewers or the tanks connected with them is

collected in large quantities; but it does not absolutely require this free exposure to air to set up putrefaction, there being always a sufficient supply of oxygen furnished by the agitation taking place in sewers. To the gradual putrefaction of solid matters is attributable the fact that although, if sewage is filtered, a clear liquid, almost devoid of smell, may result, this comparatively inoffensive condition does not last long. The liquid still contains animal and vegetable matters in solution, and is anything but WATER. It is liable to speedy putrefaction, and consequent noxious smell, with the production of a further quantity of suspended matter, rendering it again, though in a less degree, turbid.

In addition to organic matter, the filtered liquid contains all the soluble mineral compounds of the sewage, and in most cases is charged with carbonic acid, and with more or less sulphuretted hydrogen, both of these being products of the decay of animal and vegetable matters.

The object of irrigating with sewage in any way is to make use, where possible, of the useful constituents upon the land, and to bring the effluent water to such a state of purity as will satisfy the requirements of the law.

SURFACE-TREATMENT.

There are a great number of persons who, disliking cesspools, turn the whole of their sewage on open grass-lands at some distance from the house; and when one portion has become saturated, they divert the flow, it may be by a flexible hose, to another portion of the field. This surface-treatment cannot be properly called irrigation, perhaps, but it is a primitive system of sewage-disposal leading up to it. The portions of the field over which the sewage has passed show a richer verdure; and if the sewage is not permitted to discharge *too long on one place*, the grass is not rendered too rank or unfit for grazing. The proper method of dealing with grass-land which is to be sewaged, is to divide it off into plots by means of hurdles, and then to apply the dose of sewage for a sufficient time, and when enough has been supplied, the hurdles are permitted to remain up until the soil has appropriated and oxidised the sewage-matter, which it will very rapidly do if the soil be at all suitable. The cattle may then be safely turned upon it; and should a shower of rain occur in the meantime, it will be all the better for the crop. In surface-treatment of this description it is not often necessary to provide carriers or drainage, there being no effluent worth specially providing for.

TANKS FOR IRRIGATION.

Before proceeding to notice any of the more advanced systems of irrigation, it will be necessary to furnish here an idea of the outfall discharge, and how it is regulated. These tanks differ very much, and I will only describe one pattern of them. In the example shown at Fig. 284, the sewage first of all discharges into a small regulating-chamber, A, out of this chamber a pipe is led to two subsiding tanks placed right and left of the chamber, and at the ends of these pipes inside the regulating-chamber are two flap valves, shown at B. The sewage flows into the regulating-chamber by a pipe of convenient size laid to a suitable gradient. It may be necessary to employ flushing-tanks at each head of the ramification of the sewer, in order to keep the main sewers clear.

The sewage, as will be seen, enters the two tanks C and D at the option of the workmen.

In this case the tanks are sloped down, and are comparatively shallow. The tanks are fitted with double gratings, E, F, with vertical bars, about two feet apart, and the spaces between these gratings are stuffed with straw litter, or with land refuse, or some other material easy to obtain. This filtering-medium, whatever it may be, is weighted down by means of a plank, and altogether it speedily forms a most efficient strainer for the sewage, arresting by this simple contrivance the whole of the solids.

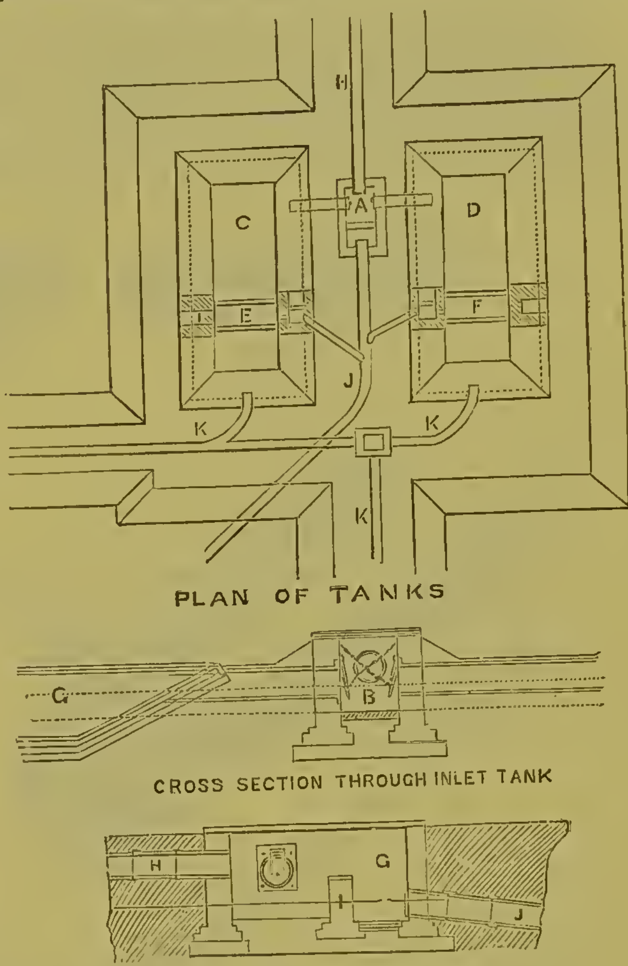

Fig. 284.

As will be seen by the longitudinal section of the regulating-chamber A, which is given below at G, the sewage enters the chamber by means of the pipe H, which pipe must be brought up to about eighteen inches above the ordinary level of the ground when it is flat-lying. In the regulating-chamber a gauging-weir, I, is fixed, which regulates the flow of the storm-water; and this weir is set at such a height that during periods of excessive rainfall, the storm-water flows over it, and passes direct to the outfall-pipe J. This provision is made because at such periods an excessive volume of water would damage the crops on the irrigation-beds, especially if the brook or river into which the effluent water discharged were at the same time in a state of flood. The addition of a small quantity of sewage which would at these times be conveyed to a brook or river would be almost infinitesimal. The overflow-pipe, J, of course passes underneath the irrigation-beds, and would enter a brook or river at a suitable level. An overflow is also provided in the settling-tanks themselves in case of accident.

After a time it is evident that the settling portion of the tanks, C, D, will be full of more or less solid deposits, and when this accumulation takes place, the water is drawn off by a valve, placing a few bricks before it by way of a rude filter. When the water has been all run off in this manner, the contents are then allowed to dry for a few days, and afterwards wheeled away into a compost-heap, which is subsequently carted away for putting upon the land, or dug in upon arable land. Not very much can be said about the worth of this material. It pays for cartage, and little more can be said regarding its value.

After the sewage has passed through the strainers, E, F, it has the appearance of simply dirty brown water, and this is led directly into the sewage-carriers, K K K, then into the branch carriers, and so on all over the ground.

THE FLAT-BED SYSTEM OF IRRIGATION.

Supposing the sewage from the house or village to have passed through the regulating-chamber into the settling-tanks and through the filter, it is led in open carriers to the ground to be treated. For example, a piece of land is shown at Fig. 285, and this irrigation-area was laid out so as to divide it in beds. First

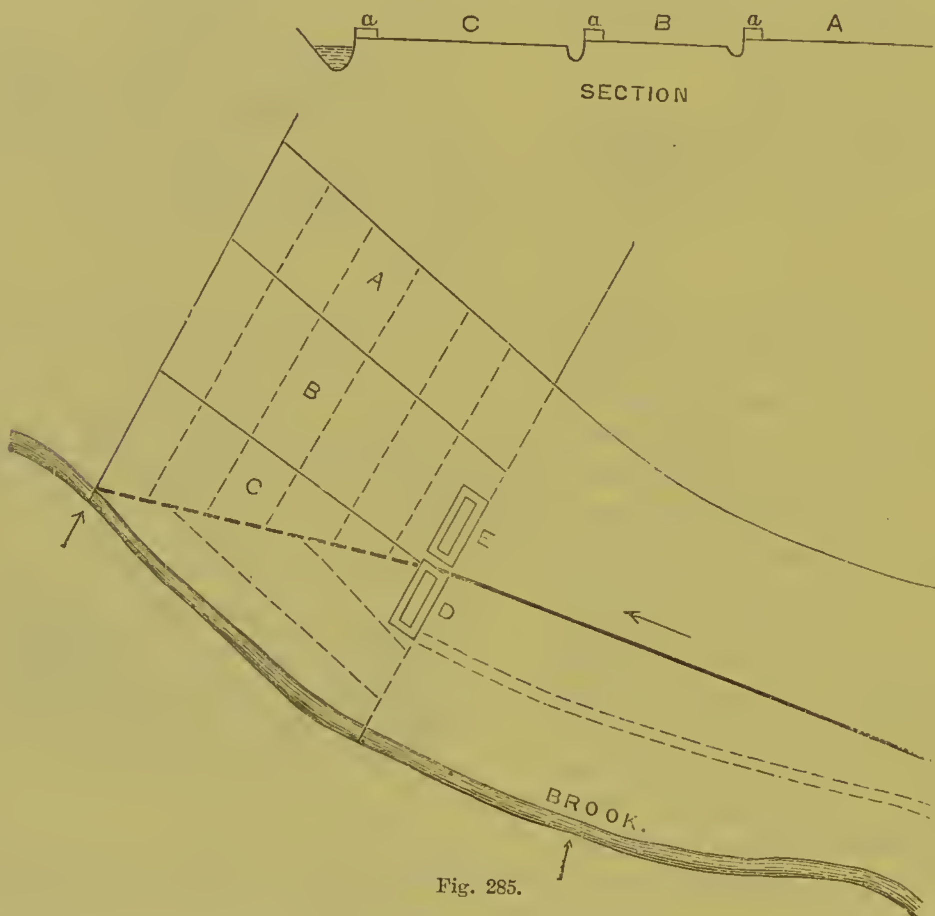

Fig. 285.

of all the turf was ploughed off, and then its higher portions were ploughed so as to level it down until each bed was made level. The irrigation-area was then thoroughly under drained to a depth of six feet, these drains being made of three-inch agricultural pipes laid about six yards apart. This formed the permanent bed, and as the ground was in this case semi-porous—by which is meant loam with a little washed down clay—the under-drainage has proved very effective, and has had the practical effect of converting the whole of the irrigation-area into one large filter-bed.

In the example drawn at Fig. 285, the land is irrigated on the flat-bed system, the site being divided into three beds, A, B, and C. The settling-tanks are shown at D, E, the sewer by the thick black line, the overflow and main under-drain to the

brook by the thick dotted line. The light dotted lines show the underground agricultural pipes which form the permanent bed, and drain into the main underground drain. The three beds into which this land was divided, as is roughly shown in the section, Fig. 285, are so arranged that each bed could be flooded at will. To confine the sewage upon the land no kind of special pipe was required, but simply pieces of turf laid along the divisions of the beds, as shown at *a*, *a*, *a*.

Sewage-irrigation works have now so largely increased in numbers and extent, that it has become necessary to produce appliances by means of which the sewage may be utilised in a simple manner, and with the least possible offence to the neighbourhood. No smell arises from fresh sewage when it is placed upon the soil,

Fig. 286.

Fig. 287.

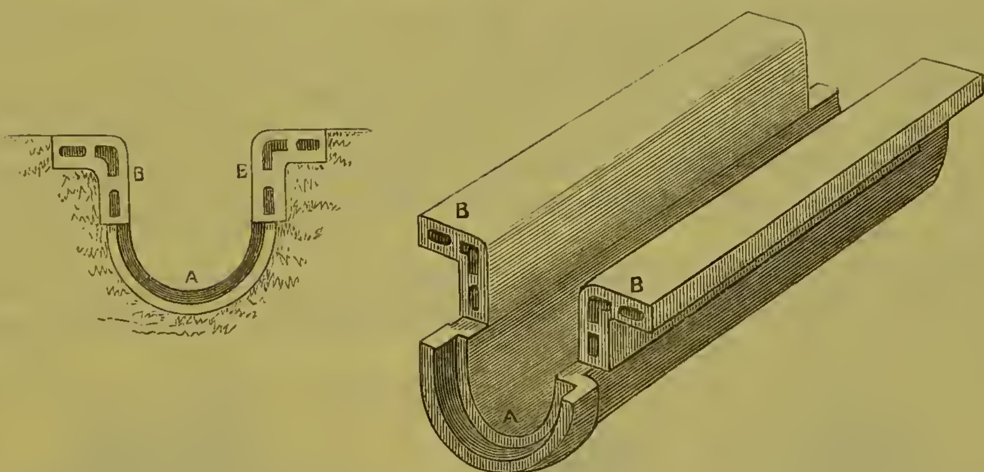

Fig. 288.

but if it be kept there, and remain especially on the sides of open distributing ditches, an offensive putrefaction will ensue.

Hence, in some soils especially, it has become necessary to discard simple earth channels as distributers, and provide concrete stoneware or other conduits which have no irregularities of surface, retain no floating impurities, are easily cleaned out, and do not encourage vegetation inside them.

Figs. 286 and 287 illustrate ordinary carrier-pipes for sewage, and these are made either with or without sockets, as shown. These are the simplest forms which are made, and if properly placed afford great advantages over the ordinary earth channels, as previously explained.

An improvement upon the ordinary carriers just described is obtained by the use of moulded copings (Fig. 288), also of glazed stoneware, and these enlarged conduits vary in dimensions, so as to be suitable for all circumstances. The flange, or projection, at the top of the coping, marked B, which surmounts the pipe, A, is very useful, inasmuch as it forms a clean and easily available footpath for the attendant. Goods of this description are not so expensive as might be thought, and where the irrigation-ground is small and a pride is taken in it, these improvements

are really desirable. Fig. 289 gives an example of a flange, or projection, at the top of the coping, where one side is fixed lower than the other, in order that the overflow may pass from the lower side only; and pipes of this description would be

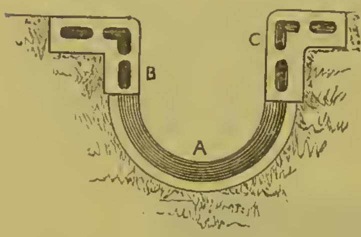

Fig. 289.

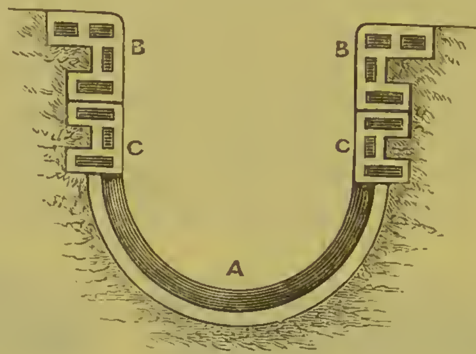

Fig. 290.

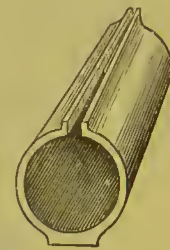

Fig. 291.

of use in irrigation-beds, such as that given at Fig. 285, by this means obviating the necessity of having to place the lengths of confining turf, *a, a, a.*

Another advantage of these special goods is shown at Fig. 290, where it will be seen that the capacity of the sewer is increased by the use of an intermediate tile, so as to raise the coping. These main carriers are made from nine inches to two feet in width, and sometimes the tiles are supported and held together by a concrete backing.

It may be useful here to point out another very available form of sewage-carrier, which I therefore give at Fig. 291. Carriers of this description are not

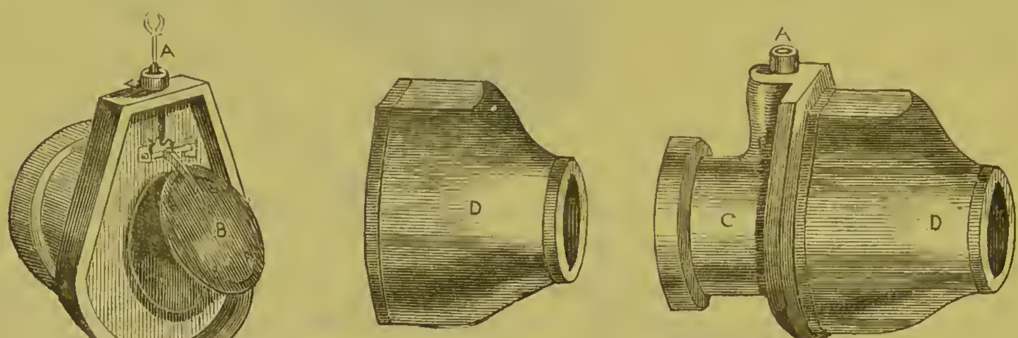

Fig. 292.

so frequently used as the open carrier already described, but they will be found useful in preventing cattle from treading down the sides of the pipes.

It will be easily understood that special contrivances of some sort are necessary in irrigation-grounds for stopping, diverting, and regulating the flow and distribution of the sewage brought upon the land. Of course, this can all be arranged in a rough-and-ready way without having recourse to costly contrivances for these purposes; but there can be no doubt that the more effective method of performing the work is by using stoneware sluice-valves, such as I draw at Fig. 292. The valve-apparatus is here given in separate portions, so as to show its construction. C is the carrier-pipe, B the valve, and A the screw which works it. The socket is shown at D, and from this the sewage is delivered to the other beds at will. It is not, however, common to make use of sockets when small pipes only are required.

Fig. 293 shows a very simple and comparatively inexpensive contrivance for stopping and diverting the flow of the sewage-distribution; and the use of these will be noticed farther on.

It may here be mentioned that most potteries will undertake the manufacture of any special goods which may be considered applicable by the managers or attendants of sewage-farms. If the main carriers are composed of these Doulton's specially-made pipes figured above, they will work well at a gradient of one in a thousand, but if the carriers are of earth or clay, not more than one in six hundred will be found advisable.

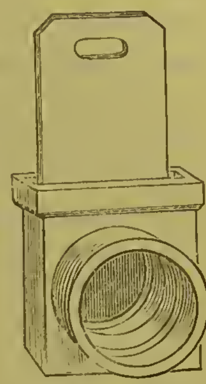

Fig. 293.

CONTOUR SYSTEM.

The manurial value of sewage, when judiciously applied, is so well known that many systems have been devised to properly prepare land, so as to realise to the greatest extent its value. At the same time, the arrangement of the land must be such as to permit of the abstraction from the sewage of those compounds which are most valuable to the growth of plants, due attention being of course paid to the purity of the effluent.

I have given a short example of an irrigation-plot where the flat surface treatment has been resorted to, but there are several others that I might as well now explain.

Fig. 294 gives an imaginary sketch of what is called the catchwater, or contour system. By this is meant the arrangement of the land into different levels, so that each level shall be able to retain the sewage separately until it is sufficiently drenched. Sometimes it will happen that the sewage will be brought upon land by simple gravitation in such a manner, that the sewage passing into the carrier A will readily be applied upon the three different levels of plateaux by way of the carriers B B, command being had over the whole, as the attendant may think fit, by means of the stops marked C C. At other times the house or farm may be below the level of the land which it is found desirable to irrigate, in which case recourse must be had to pumping up the sewage into tanks at the top of the slope.

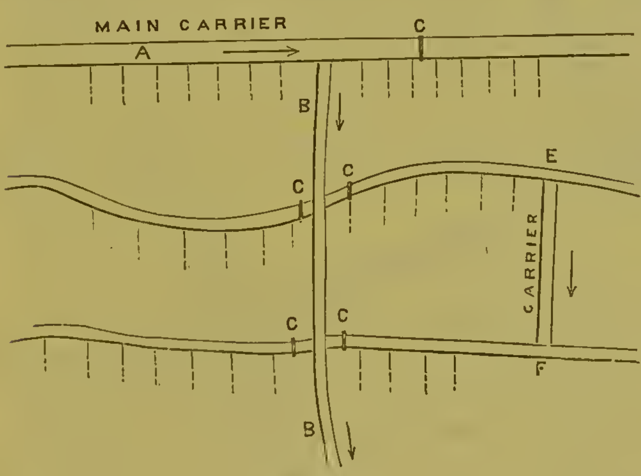

Fig. 294.

This is a very simple form of irrigation when once the beds have been properly prepared, and it is perhaps the easiest to keep in proper maintenance. It is advisable, however, not to make the beds too large, and to make them as flat as possible. For instance, the distance from E to F would be from 50 to 80 yards.

Sometimes, in order to be able to collect the deposits and silt which accrue from

the sewage, it is desirable to provide small pits in the line of the open main carriers at intervals of about 100 yards, and some attention to this provision will be found useful. The main thing, however, to bear in mind is that the greatest error which can possibly be made is in over-dosing the land, and drenching it with sewage.

Hence, separate beds are prepared and treated in rotation. The grass, for instance, which grows upon land over-saturated with sewage becomes in time of the very rankest kind, which no animal will consume, and in time fœtid and dank growths unknown to the neighbourhood will prevail.

OSIER-BED TREATMENT.

I have already given an example in the previous chapter of a simple osier-bed ; but I will give now a somewhat more extended instance. This is also on the flat-

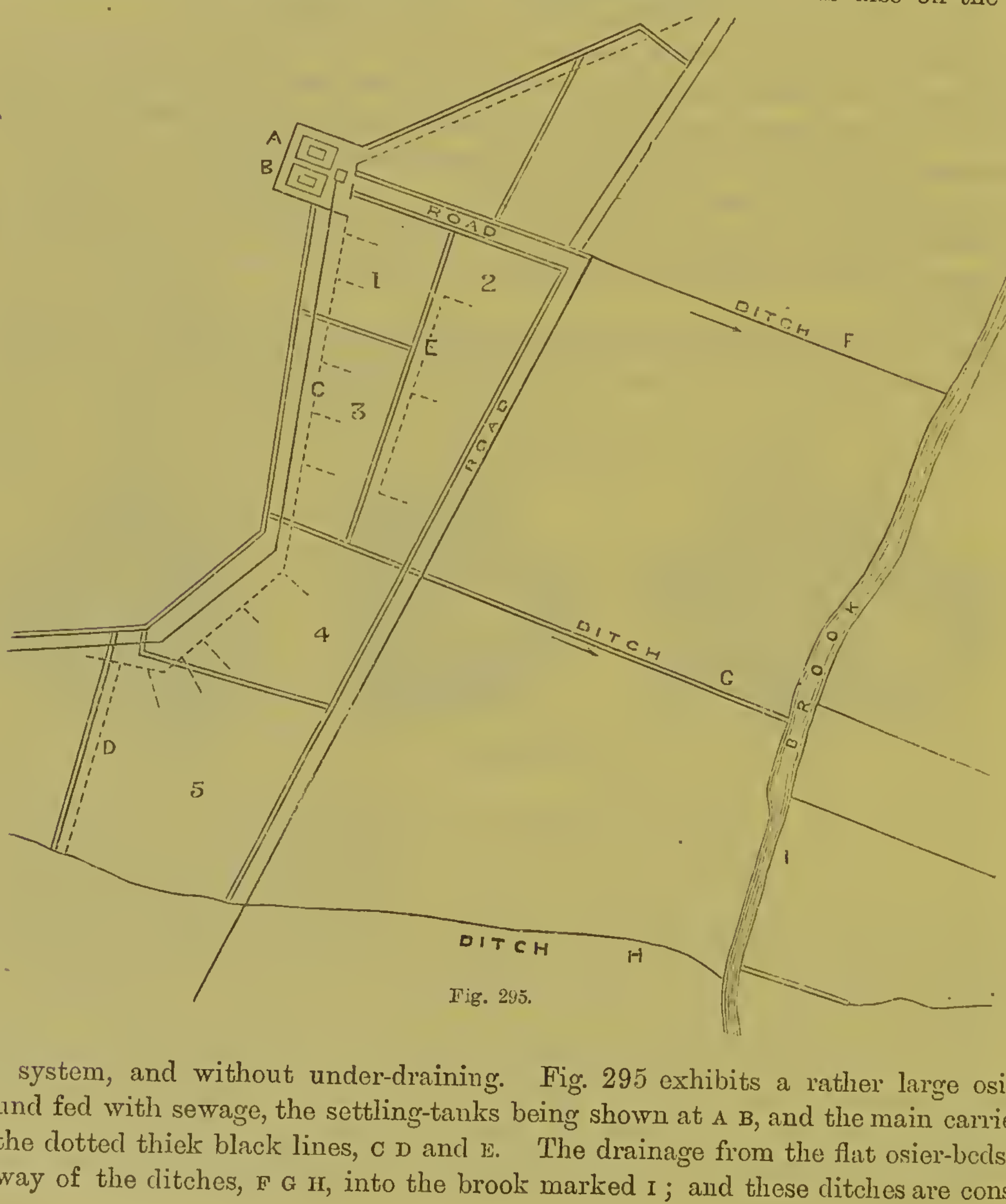

Fig. 295.

bed system, and without under-draining. Fig. 295 exhibits a rather large osier-ground fed with sewage, the settling-tanks being shown at A B, and the main carriers by the dotted thick black lines, C D and E. The drainage from the flat osier-beds is by way of the ditches, F G H, into the brook marked I ; and these ditches are conse-

quently kept well deepened and cleaned out. As will be seen, the five plots are treated upon the flat-bed system previously described.

The osiers to be planted in the osier-bed must be of the kind suitable to the particular soil, and it is not an unwise thing to consult some neighbouring nurseryman before deciding upon the exact species, or the alternating species of similar plants which are to be employed.

Osiers, or similar plants, calculated for speedily licking up the sewage, and converting the plants into saleable "wands," should always be planted sufficiently apart—say at distances of three feet—so as to allow the beds to be regularly cleaned out when necessary by horse machinery. Osiers, as a rule, grow all through the summer and winter, and are best cut down in the early spring, when the sap is beginning to rise. When they are reaped, or soon after, it becomes necessary to pass the horse-hoes over the beds, so as to make a thoroughly clean site, free from weeds and grass which would otherwise grow up and keep the osier-shoots from the sun. The spaces between the plants should be hand-hoed.

One of the best and most profitable methods of disposing of the sewage of a village or mansion is by utilising a portion of ground for the growth of osiers. As a rule, the point of outfall being at the lowest level of the district, is usually of a swampy nature, peculiarly suitable for this class of cultivation. When laying out land for this purpose, under-draining is found not to be very practicable, as I have before mentioned, the reason being that the roots of the osiers extend in long fine filaments over considerable distances, and ultimately reach the under-drain. When a strip of osier-root reaches these under-drains, it soon passes into the inside, and speedily grows into a matty-like material, which eventually closes up the pipes. Instances are not uncommon where this rooty material has been taken out measuring from twenty to thirty feet long. In laying out an osier-bed, it is always preferable to dispose of the land in flat beds, surrounded by deep ditches, making, if needs be, each plot into an island. All round the bed a ridge about nine inches high is formed to confine the sewage until enough has been absorbed by the earth. The leads taken from the main carriers to evenly flood the beds are shown by the thin dotted lines.

PANE AND GUTTER SYSTEM.

This is another method of treating sewage. Supposing, for instance, a piece of ground, tolerably flat, is to be laid out to intercept and purify the sewage of a large mansion and offices, the procedure might be as under :—

The coarse stubble or surface would be pared off to the full depth of the roots, by means of proper paring-tackle, and then burnt in stacks, so as to be spread over the surface when the beds were formed. All the surfaces too high to bring the land to proper levels for the distribution of the sewage would be then ploughed off. The land would then best be profitably cultivated with steam-cultivating tackle to a depth of fifteen inches, twice over, the second time as nearly as possible at right angles to the first time; and the surface would be worked down afterwards by double harrowing. After this was done, the surface would be ploughed up in ridges or furrows, in directions and levels to facilitate the flow of sewage to every part. The beds would be about 40 ft. wide, each with feeders along the ridges and collectors along the furrows, delivering into the main catchwater-drains, directly

over the 9-in. main under-drains, which had previously been laid, together with 6-in. and $2\frac{1}{2}$-in. branch underground drains laid to available falls. Fig. 296 gives an illustration of a bed laid out on this pane and gutter, or ridge and furrow, system.

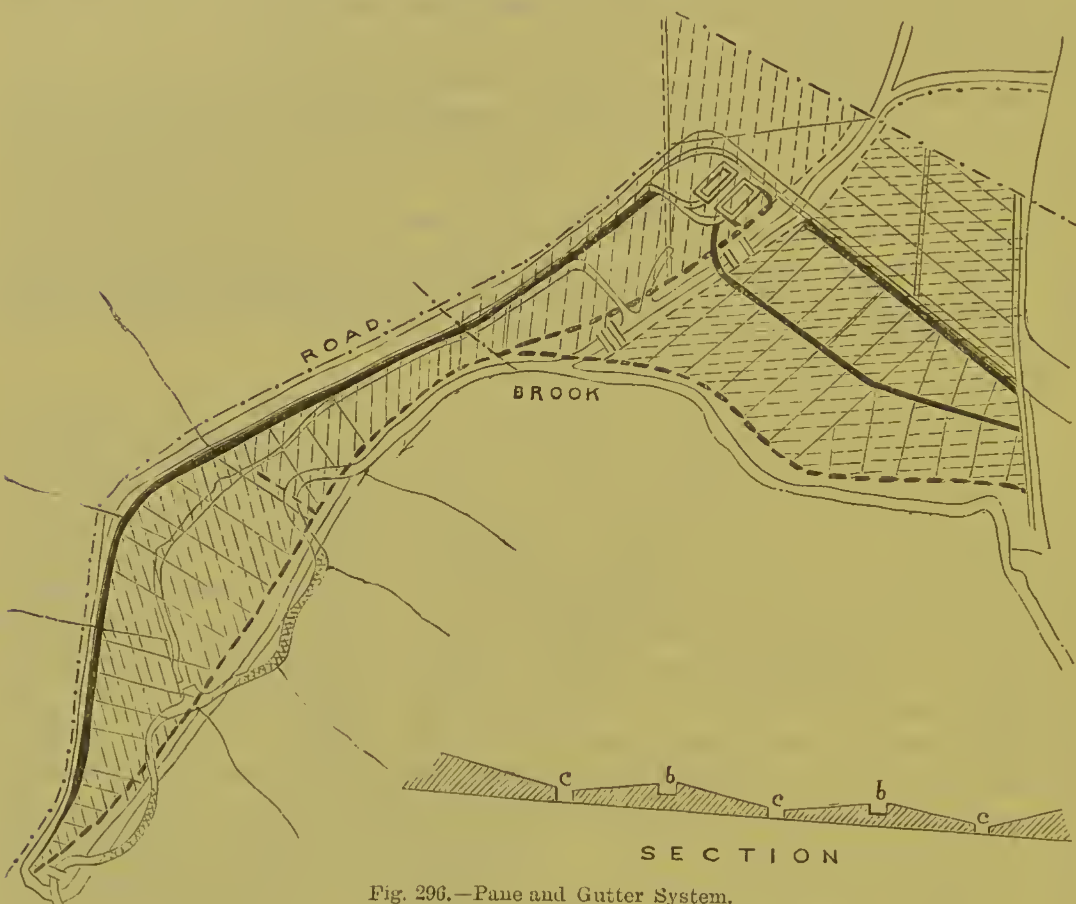

Fig. 296.—Pane and Gutter System.

The main carriers are shown by the thick black lines, the feeders by the thin black lines, which are forty feet apart; and the underground drains are shown by the fine dotted lines, these being collected into the dark dotted line, which eventually delivers into the brook. This example will also show how necessary it sometimes is to divert a brook (see the cross-hatched lines), so as to acquire straight lines, or a speedier delivery of the running water. The slopes from the feeders *b*, to the catchwater-drain *c* (see section), should not be more than one in forty. The catchwater-drains are generally twelve inches wide and six inches deep, such as would be made by a plough. The main drains (see section) at *b* are generally six inches to nine inches deep, and correspondingly narrow.

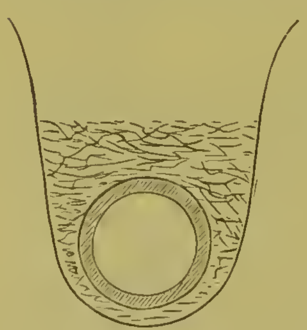

Fig. 297.

In this example the underground drains are formed of $2\frac{1}{2}$-in. agricultural pipes, laid in the trench and on the top; ashes, pit-bind, or thorns are placed above the pipes, as shown in Fig. 297, so as to provide a porous material next to the pipes. These underground drains were laid about fifteen feet apart.

COMBINED TREATMENT.

Sometimes a piece of land in the neighbourhood of a mansion or large establishment is not very well adapted for irrigating-purposes, since it may happen that the land upon which the sewage is required is partly below and partly situated above the house, rendering necessary the pumping-up of the sewage to the higher plots.

Fig. 298 exhibits a piece of ground requiring a complex treatment, or which may require such treatment, according to the wishes of the owner. Supposing the house

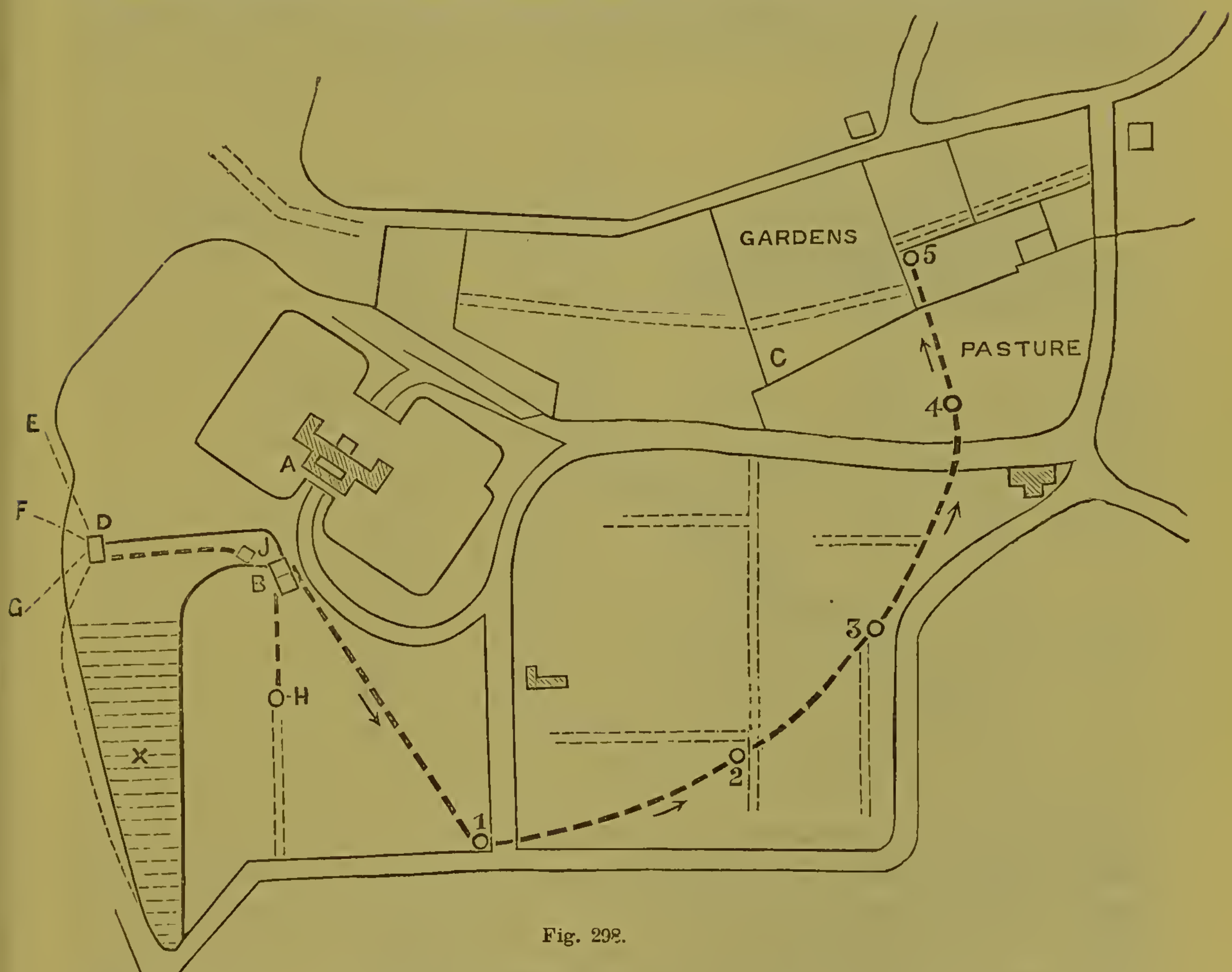

Fig. 298.

were situated at A, and the subsiding-tank at B, the whole of the sewage being strained there, it will easily be seen that this sewage must be pumped up into the gardens and pasture-land shown at C, which in this case was some twenty feet above the house-level, and forty feet above the level of the subsiding-tank at B.

When the pumping-up of sewage becomes a requirement, it can be carried out in several ways. In this case the sewage, after being strained at the subsidence-tank B, is conveyed to a set of plunger-pumps worked by a water-wheel there, supplied from various springs, E, F, and G, at a higher level. The level of this wheel is forty feet below the subsidence-tank. Before it was considered necessary to irrigate the plots, C, on the highest level, these wheel-pumps were quite able

to perform the pumping-up to the ground-level H. This land being of a greensand character, no under-draining was necessary, the ground taking readily up the whole of the sewage. The difficulty was, indeed, to lead the sewage over the land; and Doulton's carriers became a necessity, to be used at very frequent intervals as subsidiary carriers in addition to their use as main carriers.

When it became desirable to treat the upper portions of the land situated at C, which are chiefly market-gardens and pasture-land, it was found necessary to specify for the erection of additional pumps, say, for instance, double-acting horizontal pumps, worked by a gas engine placed at J. The delivery-pipes, of three-inch cast-iron, are carried along the single thick dotted line to points of output marked 1, 2, 3, 4, and 5, which are respectively in such situations as to command the

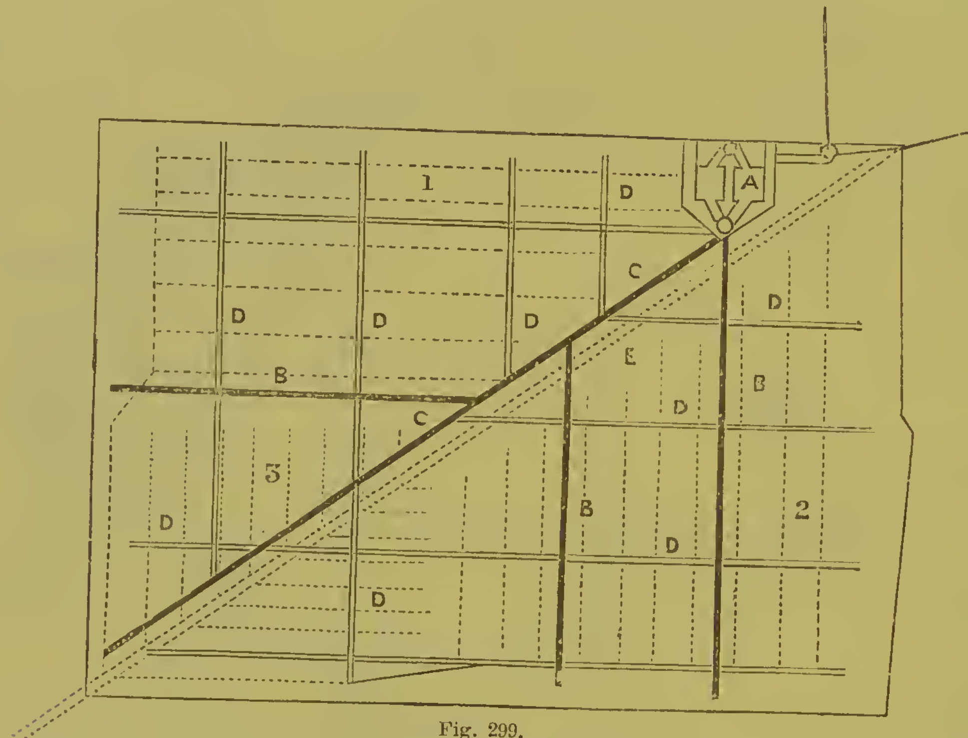

Fig. 299.

surrounding land. Valves are fixed at each of these points, which can be so adjusted as to regulate the volume of sewage to be discharged. The delivery from these valves is directly into the Doulton's carriers previously referred to, and shown by the double dotted lines. These carriers are permanent in character, and the roads are made alongside them. The plan does not indicate the subsidiary carriers, because these have to be formed according to the requirements and circumstances of each crop.

It is not always convenient or desirable to apply sewage to land under a crop; and as, moreover, any machinery will occasionally get out of order, it is advisable, whenever it can be conveniently done, to prepare a portion of the land to act as an intermittent irrigation-bed. Such a bed is shown at X, Fig. 298, and it may take the form of an osier-bed, or plots for the growth of mangel, turnips, cow-cabbages, or other grossly-feeding plants. These beds would at all times be available as a safety-valve for the escape of the sewage. And were the house at A of a smaller description without upland property, the irrigation-bed at X

would be quite sufficient, no pumps being required, since the sewage would flow there by gravitation.

In this case the piece of ground at X slopes rapidly down a dell; and this being so, the underground drains are taken straight up the slope at the usual depth, as in the case of railway-cuttings. This is not the usual way of providing an intermittent bed, but here, owing to the conformation of the ground, little else was possible.

Another example of a combined treatment is shown at Fig. 299. In this case the whole of the land is almost flat, there being scarcely three inches difference in level at any part of the plot. In consequence of this, the tanks are embanked to a height of about twenty-one inches, so as to obtain a fall over the beds. The sewer to the tank is carried in an embankment after the fashion shown at Fig. 300, where the sewer-pipe is shown supported upon a 4½-inch wall, built upon two set-offs of brick in mortar. The thin wall is usually built dry, so as to compensate a little for settlement. Upon the plan (Fig. 229), the tanks are shown at A, and the main carriers by the strong black line marked B B. These are laid to a gradient of one in a thousand. They run from the main carrier, C C, dying away from 18 inches in depth to nothing at all, sodded up at each side. The feeders from the main carriers, which are marked C and B, are shown by the double lines, each marked D, the main underground drain which drains the bed is indicated by the double dotted line E, and the ordinary underground drains by the single dotted lines. It will be observed that this is another example of the flat-bed system in plots.

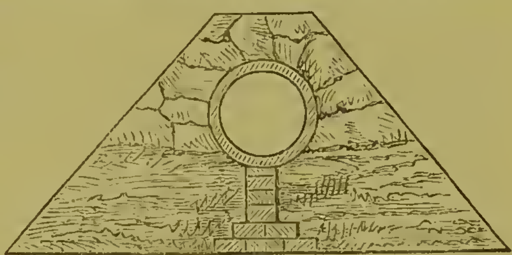

Fig. 300.

There are several peculiarities about this example which are worth notice, and one is the intermittent character of the manipulation. It will be seen also that the beds are divided into three grand plots, the one marked No. 3 taking the form of a square nearest the outfall of the effluent water.

This No. 3 bed is provided as an intermittent filtration-bed. For instance, when the plots 1 and 2 are in cultivation—that is to say, with a growing crop upon them—it is found undesirable to supply these beds with a further supply of sewage. Hence, the laying-out of bed No. 3 as an intermittent one. This intermittent bed, then, really becomes a filter for the sewage, but it would be subdivided in such a way that some portion of it should be under crop at all times.

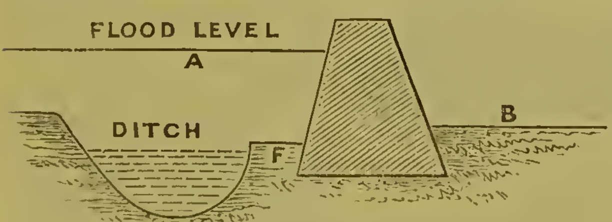

Fig. 301.

One interesting feature in this case lay in the fact that the ground was not only very level, but that it was flanked by a stream which very frequently rose to a flood-line, and would have overflowed the site of the meadow on which the irrigation-beds were eventually placed. This necessitated the formation of an embankment around the whole parallelogram, which was accordingly built in the fashion shown at Fig. 301, the embankment being made of sods and earth laid closely together, and somewhat keyed into the soil, as shown.

The result of this precaution was, that when the water was up to the line A, B, were kept normally dry and in working order. When the flood lasted, however, for several days, it can easily be understood that the influx of sewage would very soon change the arrangements inside the bed after the flood-valve at the bottom of the bed, was closed, inasmuch as the bed would be charged with simple sewage; and that should the flood last a considerable time, the sewage would fill up almost to the level of the flood. In cases of this kind a common practice is to turn the whole of the sewage into the flood-water, or a portion of it, and by this means keep the action of the irrigation area intact; but the resort to this must be left to the wisdom of a skilled attendant.

It is a curious fact, but nevertheless true, that when even a moderately porous ground has been under-drained for several years, defined courses seem to have formed themselves in direct connection between the surface of the irrigated field and the underground drains, so much so that it is found almost impossible to regulate the flow of the sewage over the whole area which has been taken in hand. In order to overcome this difficulty, and bring the sewage to the roots of the crop, it is sometimes found necessary by the attendant to insert stops at the foot of the main under-drain at sundry times, so as to retain the sewage until it has reached the surface of the irrigated area. This remark would apply to places where there was a paucity of sewage-delivery.

SEWAGE CROPPING.

This can hardly be called a separate system, because it simply means the rough-and-ready, but nevertheless effective, method of raising crops upon irrigated land. Nor will it be necessary for me to explain at any length the many arrangements which are resorted to in order to benefit the crops which are grown upon land treated by sewage. If a graduated scale were given from the most ordinary produce of a sewage-farm down to the requirements of a kitchen-garden, it might be said to take the following lines:— Osiers, black oats, rye grass, mangels, cabbages, and ordinary garden stuff, leading up lastly to the luscious strawberry.

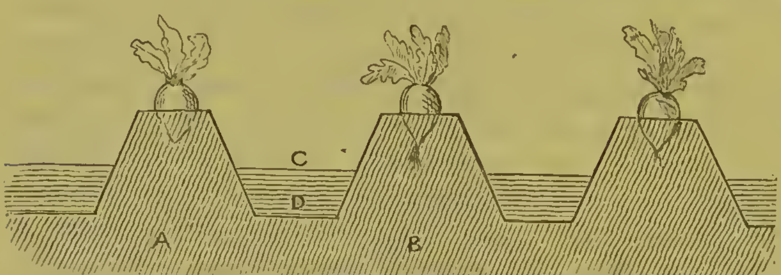

Fig. 302.

Supposing that the land were to be laid out for the production of, for instance, crops of mangels, the beds would be ploughed into something after the fashion shown at Fig. 302, the distance between the bed-centres A B being about two feet, and the depth of the furrow C to D, down which the sewage is led, about nine inches. The irrigated area would be, of course, under-drained, say, at depths of five feet, and at distances apart of from five to twenty yards, depending entirely upon the nature of the soil. A crop of the kind of pabulum best suited for cattle, perhaps, after all, pays the best.

In the cultivation of radishes, leeks, or even strawberries, the method of laying out the bed is not dissimilar. Beds are formed usually about three feet by four feet in extent, and the furrows are fed with sewage, after the style shown at Fig. 303, the irrigating-medium, which in these cases has no communication with the surface or the upper portion of the plant, giving each plot a resemblance to an island. The underground drain is usually about three or four feet below. The irrigated beds may be any size compatible with the special requirements, viz., from three feet and so on in width to eight or ten feet long.

Fig. 303.

EXAMPLES OF IRRIGATION.

I will now proceed to furnish some interesting examples of the various methods of dealing with sewage on the land, and I am better enabled to do this by the kindness of Mr. Rogers Field, M.I.C.E., B.A., the inventor of the well-known flush-tank. The following examples of irrigation were conceived and carried out by him.

Fig. 304 shows a plan to a scale of 200 feet to an inch of the Charterhouse School, Godalming, from which will be seen the general disposition of the large range of buildings occupied by that school. This building was designed by an eminent architect, and is situated in a position which would perhaps be difficult to equal for beauty in any part of England. The example is here given as being one of singular interest, and showing what may be done in matters of sewerage. In the present paper, however, I have to deal merely with the drainage-arrangements, and not with the sanitation of the building generally. The building appears to have been favourably situated for the carrying-out of a proper system of sewage-disposal, but we find that this was not accomplished in the first instance—viz., when the buildings were erected. The system of sewage-disposal originally resorted to was that of absorbing cesspools excavated where convenient, and fourteen such cesspools were, or had been, in use up to the time when it was considered necessary to depart from such system. The plan in Fig. 304 shows the system of sewage-disposal designed and carried out to supersede the former dangerous method. The strong dotted lines upon the plan indicate the course of the new drains, which it will be observed are laid out in straight lines from point to point, with manholes and inspection-chambers at all junctions, and bends for access to the drains for examining them. The manholes are covered by iron doors, and the inspection-chambers have stone covers, which can be taken up by removing the ground above them. The drains have in every case a good fall, so as to be self-cleansing; but as an additional security special means of flushing were provided by utilising the flush from baths and laundry tanks. The drains are ventilated by gratings and openings.

The drains were laid with glazed earthenware pipes, and special attention was given to the jointing and to the gradients being in every case true to line. The

Fig. 304.—Drainage of the Charterhouse Schools, Godalming.

ventilation-system was fully secured, and separate means were taken for the disposal of the surface and roof water by special conduits for that purpose. When the new system of drainage-works had been carried out, the disused cesspools were in every case carefully cleaned out and filled up with clean earth. It will not be necessary, while describing these works, to stop to dwell upon the details of all the arrangements provided for the disconnection and ventilation outside the walls of these buildings. Great care was taken to test all the new drains by filling them with water, so as to ensure that they were quite tight, and thus to avoid any chance of contaminating the water-supply, which is drawn from a deep well under the laundry. The rain-water drains are left undisturbed. One cesspool was converted into a tank for rain-water only, and the rain-water is kept entirely distinct from sewage-drains. In the main building dry earth-closets have been generally adopted, but there are also a considerable number of water-closets in use. This water-closet sewage and all the waste and slop water are conducted by suitable main drains laid to a proper fall and in the position shown upon the diagram, until they arrive at the point marked A, and there used for irrigation upon the land bordering the approach leading to the south-west of the building. At the point of the outfall is a small straining-chamber, which intercepts the solid and suspended matter, and which, if cleaned out every day, will prevent the formation of sludge. The amount of matter as intercepted daily is so trifling that it can readily be mixed with dry earth or ashes, and so dealt with without creating any nuisance.

From the straining-chamber the sewage flows into a brick tank, called a sewage-regulator, so contrived that no discharge takes place until it is full; when a syphon automatically discharges the contents (about 3,200 galls.) upon the land in one continuous stream. The advantage of this arrangement is that a known quantity of sewage is applied automatically to any desired portion of land, and that, by the intermittent action of the discharge, the sewage is more completely absorbed by the soil and herbage. The tank is arranged so as to avoid deposit, but a small quantity of slime will necessarily collect in the bottom. In order to remove this, a wooden waste-plug is lifted up when the tank is nearly empty, and all the slime swept out through the hole. The tank is then allowed to fill again, when the plug is once more lifted, and the slime carried forward on to the land. From the tank the sewage is conducted down the land to the irrigation-ground in pipe carriers, with outlet for distribution at intervals. There are two penstocks in the straining-chamber, by means of which the sewage can, if necessary, be diverted so as not to flow into the tank, but into the by-wash drains, and thence direct on to the land.

Carriers are formed across the ground nearly level and on contour-lines, so that the sewage can be made to flow over the carriers and distributed equally over the surface by means of stops placed at any desired point in their course. These carriers were constructed in the simplest manner, by cutting a chase along the contour-lines and forming a lip with turfed sods, so as to maintain their form and direction in the earlier stages of irrigation.

It may be interesting here to describe somewhat in detail the manner of forming these carriers, which are similar to those used at North Camp Farm, Aldershot, for more than twelve years past.

The accompanying sketch, Fig. 305, shows a section of the upper carriers where the soil was sandy. It is found quite sufficient where the top soil is loamy, and

especially where it has been cropped and left a border of stubble, merely to dig a plain contour carrier seven inches deep, nine inches wide, and throw the material on the lower side. Such a carrier may be quite level, or have an inclination not exceeding one and a half inches in ten feet; but in loose soils and in sand it will be impossible to obtain a firm "lip" to the carrier without the aid of fresh-cut turf. This turf should be about nine inches wide at the top, and neatly laid on the excavated material, and care should be taken to prevent leakage under the turf-layer, and the back of the carrier may require to be held up in places also by turf, but as a general rule the natural slope is found sufficient. No turf requires to be placed at the bottom of the carrier, as the sewage is soon found to convey sufficient slime to render the carriers impervious. Even in sandy soils layers of turf will make carriers of any dimensions, if properly backed up on each side and trimmed down flush with a spade (see Fig. 306), and such carriers will resist the wear of flowing sewage up to a velocity of two feet per second. In setting out a carrier it is quite sufficient to put in two pegs, say ten feet apart, at the starting-point of the carrier, and let the top of the second one be, say, half an inch or a quarter of an inch lower than the first, and all other points of the carrier may be boned from the first two pegs by cross-sights, even when the curvature is considerable.

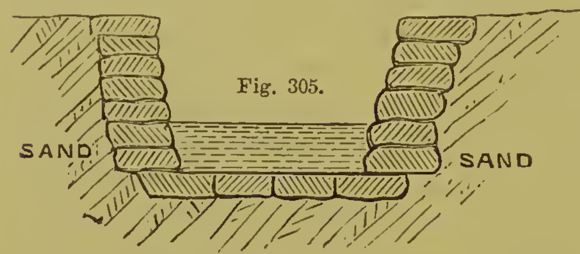

Fig. 305.

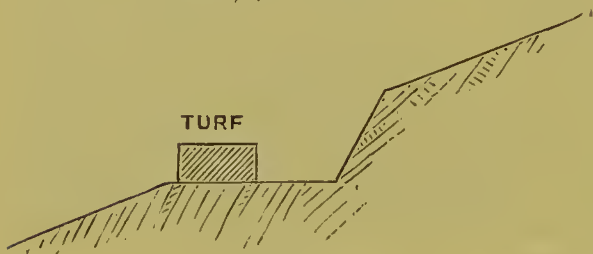

Fig. 306.

When sewage is at first admitted into the carrier, it should be carefully noticed whether it wears away the carrier at any point, and this should be at once repaired with turf or slate.

The sewage will not of itself overflow the lip of the carrier so as to irrigate evenly, and it is therefore necessary to check the flow either by hand "stops" (usually of oak, as Fig. 307), placed at intervals athwart the carrier, or by lumps of turf roughly laid in the carriers, so as to back up the stream. They cause an overflow, while at the same time allowing some portion of the sewage to pass by in the carrier, so as to be thrown out by the next stop, and so on, until the carrier is filled. The size and distance apart of "stops" must of course be regulated by the special circumstances of each case.

Fig. 307.

Fig. 308 is a plan showing the disposition of the buildings in the Sanitorium, the sewage of which has been dealt with by sub-irrigation. Here A is the Sanitorium, B is the gardener's cottage, and C and D are the plots of garden-ground subjected to sub-irrigation. The gardener's cottage at B had the small plot of land, D, for its own use, and the slops from the Sanitorium were separately dealt with as shown. In this particular instance, the earth-closets were used for the excremental deposit, there being adequate labour to give the proper attention necessary for this system.

A self-acting flush-tank, similar in principle to the syphon-tank, described when dealing with the main building, delivers bath-water, waste-water, and slop-water on the garden-land, as shown upon the diagram at C and D, so as to charge the sub-irrigation pipes. These pipes are the size of common agricultural drain-pipes, and are laid about 12 inches below the surface, on a permanent bed; the sewage flows out of the joints into the soil and floods the vegetation. The

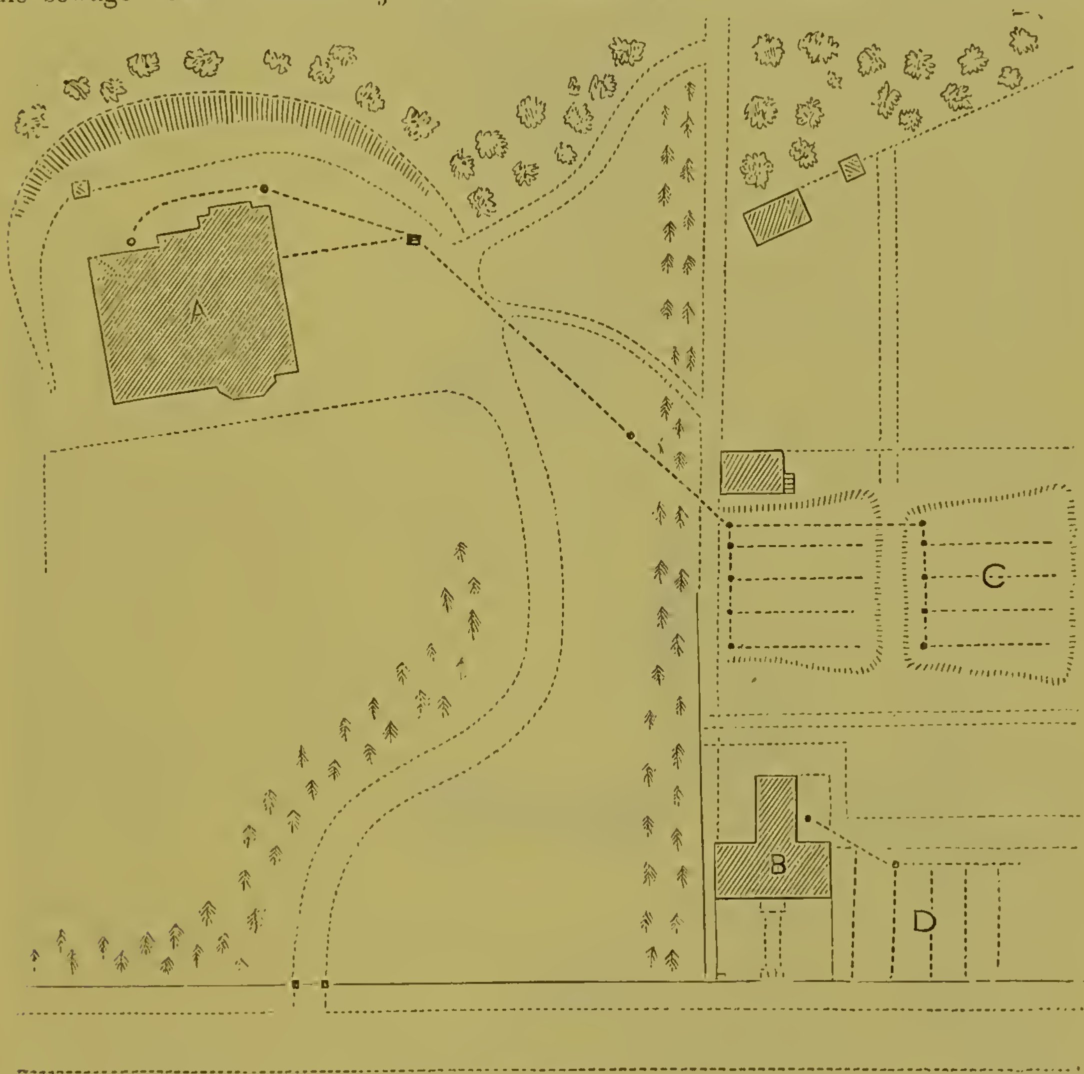

Fig. 308.

sub-irrigation pipes in time require cleansing; and the way of doing this is to open down to the pipes in several places, and carefully remove a couple of them at each place, without disturbing the permanent bed, and pass a cane or rod through the intervening lengths—thus thoroughly cleaning them—then replacing the pipes in their original position on their permanent bed. If any lengths of pipes are lifted out of position, care should be taken in re-laying them that they are made to break joint alternately on the permanent bed. The subsoil-drains were composed of 2 and 3 inch agricultural drain-pipes, laid upon permanent beds of half-round drain-tiles, laid to the proper falls.

Fig. 309 shows a system of drainage and sewage-disposal carried out at a large

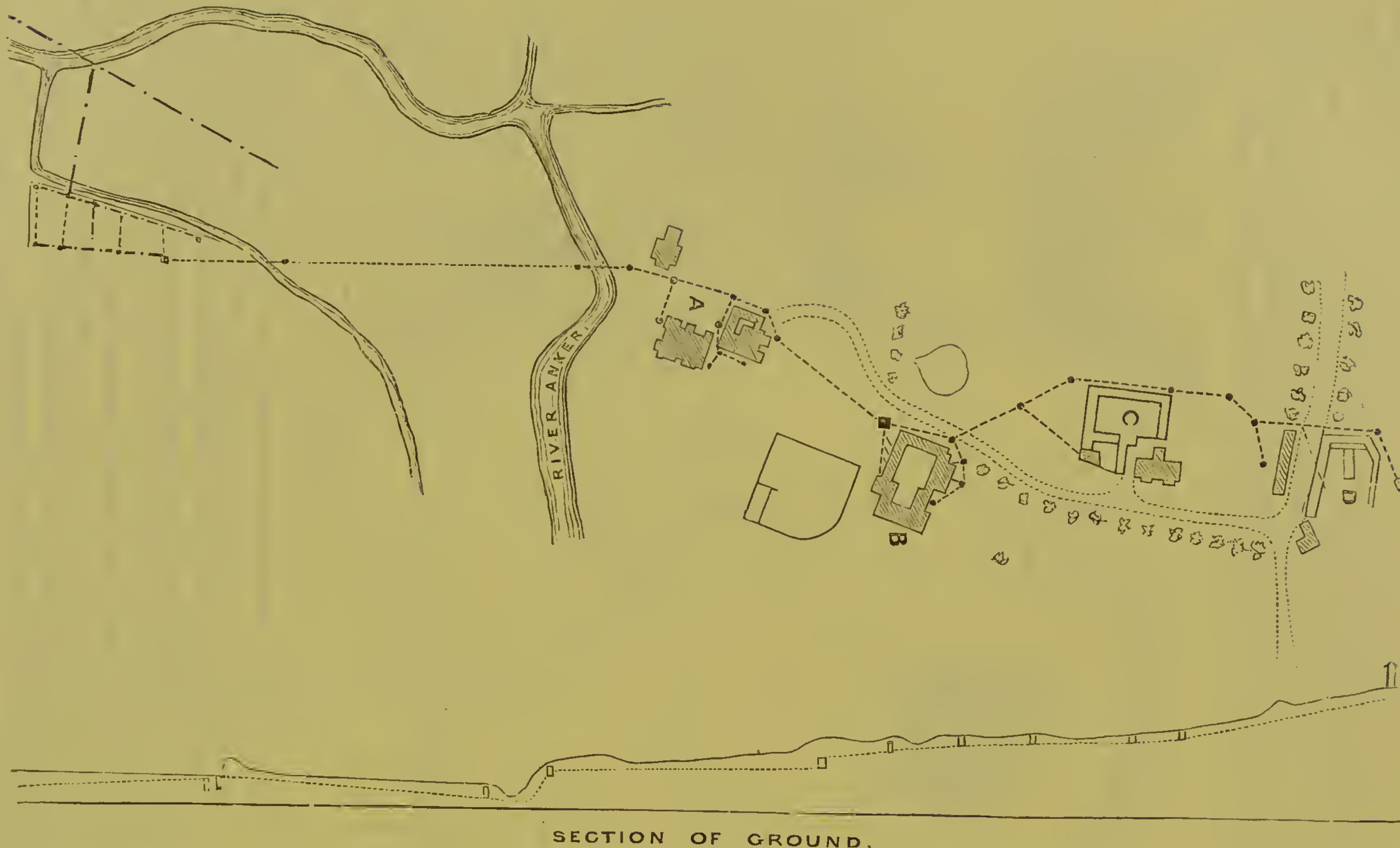

Fig 300.—Drainage of a Country Mansion near Nuneaton.

mansion near Nuneaton, and presents a most interesting case of sewage-works where the available irrigation-ground was situated at some considerable distance from the mansion, a river and watercourse intervening. The diagram here given shows a plan and section of the works as carried out. The mansion is shown at A, the stables at B, the farmyard, laundry, and rectory at C, and the village at D. The strong dotted lines indicate the course of the drains from the village to the outfall. It will be seen, on reference to the diagram, that the river divides the irrigation-ground from the buildings to be dealt with. The difficulties which arose in this case were the slight fall available for the main drain and the liability of the land near the river to flood. It was thus necessary to cross the river by some means in order to reach suitable land for irrigation-purposes, and even then it became imperative to embank a portion. To render this scheme feasible, it was also necessary to improve the existing deep land-drain, which had its outfall at the mill-tail some distance down the river. A gain of 4 ft. 6 in. in level was obtained over what would have been possible supposing the ground to have been under-drained direct into the river at the irrigation-plot, and the land would, moreover, have been water-logged at flood-times.

To render the drainage workable with such a flat fall as that from above the stables—viz., 1 in 330—was a matter of some consideration, and special flushing was arranged in the village for cleansing this portion. A flushing-chamber was provided, shown upon the diagram, near the corner of the stables, for discharging the sewage suddenly down the lower portion of the system. In order to convey the sewage across the river, it was necessary to construct a syphon. This syphon, as will be seen from the section on the diagram, is of peculiar construction, to avoid, in this particular case, the unsightliness of an embankment. The syphon is composed of a cast-iron pipe, 7 inches in diameter, with proper inspection-manholes.

The irrigation-ground is shown upon the diagram and the deep land-drain is shown by a chain dot. The sewage arrives on to the irrigation-ground through the syphon by the delivery flush-tank, as before mentioned, and is taken along by carriers in the usual manner. The area of the irrigation-ground is one acre, and serves for the population of about 100 persons. The subsoil is irregular, and consists of gravel and sand, with clay underlying, the depth of gravel and sand varying from 2 feet 6 inches to 5 feet. The irrigation-ground is under-drained in the usual manner to a depth of 4 feet to 4 feet 6 inches. The deep drain is filled in with puddled clay, so as to make the sewage enter from the side and not percolate directly downwards. The total length of the syphon is 680 feet, and it was carefully calculated so as to take the full flow of sewage. Experiments made after the works had been completed showed how carefully this had been effected.

The methods of sewage-disposal previously described have been by gravitation to the outfall, and thence flowing on to the irrigation-ground. There are, however, cases where the disposal of sewage by gravitation is impossible, on account of the configuration of the ground surrounding the house; and as the following example of the drainage of a country house at Iver, Buckinghamshire, is of peculiar interest as showing what may be done in such cases, I propose to describe it at some length. The house is situated between two roads, and the only land available for sewage-disposal was situated above the level of the house.

The original sewerage-arrangements of this house were in accordance with the

usual method pertaining to gentlemen's country houses a few years since, where the sewage from the house was delivered into a cesspool, which cesspool was unventilated, and had an overflow into an adjoining ditch or brook. The diagram, Fig. 380, shows the house and the surrounding property attached, where A is the mansion, and B the stables. The position of the cesspool which took the sewerage is shown at the point marked G, and was so situated that the whole drainage gravitated into it, this portion of the property being the lowest in regard to level.

It became necessary, when the house was enlarged, to consider in what manner a complete scheme for water-supply and sewerage could be best carried out. Mr. Rogers Field was intrusted with the matter, and the works to be described were designed and carried out by him.

The first question which naturally presented itself in considering such a scheme was that of outfall for the sewers, and this point had of course to be taken in relation to the very important one of disposal. The lowest point of the property where the sewers could naturally gravitate was first considered; but it so happened in this case that the ground around this lowest point was of such small extent, that it was quite insufficient for any satisfactory method of sewage-disposal.

The sewage might have been received into a cesspool at this point, but a little consideration showed that this was quite inadmissible. The ground was impervious, so that the liquid would not soak away, even if this had been considered desirable, which, from a sanitary point of view, of course it was not. An overflow into the ditch was no longer tolerable.

Had a watertight cesspool been provided, it would have been necessary to pump out the contents into a cart at very frequent intervals, so that it might be carried away to another part of the property; and this would have been such a troublesome and costly matter as to be out of the question. Lastly, an engine might have been erected to pump the contents of the cesspool, and to deliver to another part of the property; but the situation was not at all suitable for the erection of an engine-house. The only available land for taking the sewage was on the other side of the house, so that all the sewage would have to be pumped back past the house.

It was, therefore, determined not to take the sewage to the lowest part of the property, but pumping was necessary to convey it to the most convenient point for dealing with it.

In order to determine this point, the first consideration was to find a suitable plot to form an irrigation-ground on which the sewage could be utilised and got rid of without any nuisance or damage to health through the pollution of the water-supply. At the very extreme corner of the property, and at the highest point, there was a small field of garden-ground about an acre and a quarter in extent.

Examination proved that the subsoil of the field was exceptionally favourable for the purpose of irrigation, the subsoil being a free gravel overlaid by sandy soil, and it was, therefore, decided to bring the sewage to this plot of ground.

The scheme chosen as presenting the most favourable conditions is that shown upon the diagram, Fig. 310, which may be described as follows. The house-drains, shown by the dotted lines on the sketch, are conducted outside the buildings, and carried in a precisely opposite direction to that they previously took, to the point marked E, where a tank is constructed to receive the sewage, and a gas-engine is provided to lift and deliver it along the cast-iron main, F F F.

The general fall of the land, as already stated, is towards G, so that the drains were taken, as it were, against the fall of the land. The portion of the ground between A and C is, however, practically level; and by taking the drains in this direction, the sewage is led towards its final destination upon the irrigation-ground at X, instead of away from it.

It is not necessary to dwell upon the arrangements of the house-drainage in detail, either as regards manholes for inspection, the ventilating, or the flushing-arrangements, suffice it to say these are of an excellent and complete character.

A most important feature in a scheme of this kind is in the construction of the receiving-tank. This is shown in Fig. 311 in a plan and section to an enlarged scale of the work as carried out. The sewage is received into the circular brick tank P, through the disconnecting-manhole Q. The circular tank is brought up and finished with a square shaft terminating in a louvred movable roof for ventilation. Beneath this roof is an iron tray, sliding upon wheels, and having a wire basket to receive charcoal over the whole area of the shaft. The disconnecting-manhole is for the purpose of preventing any foul air from the tank passing into the house-drains, and the charcoal tray is for deodorising the foul air before it escapes from the ventilator. As a matter of fact, however, from the peculiar construction of the tank, hardly any foul air has been found to exist.

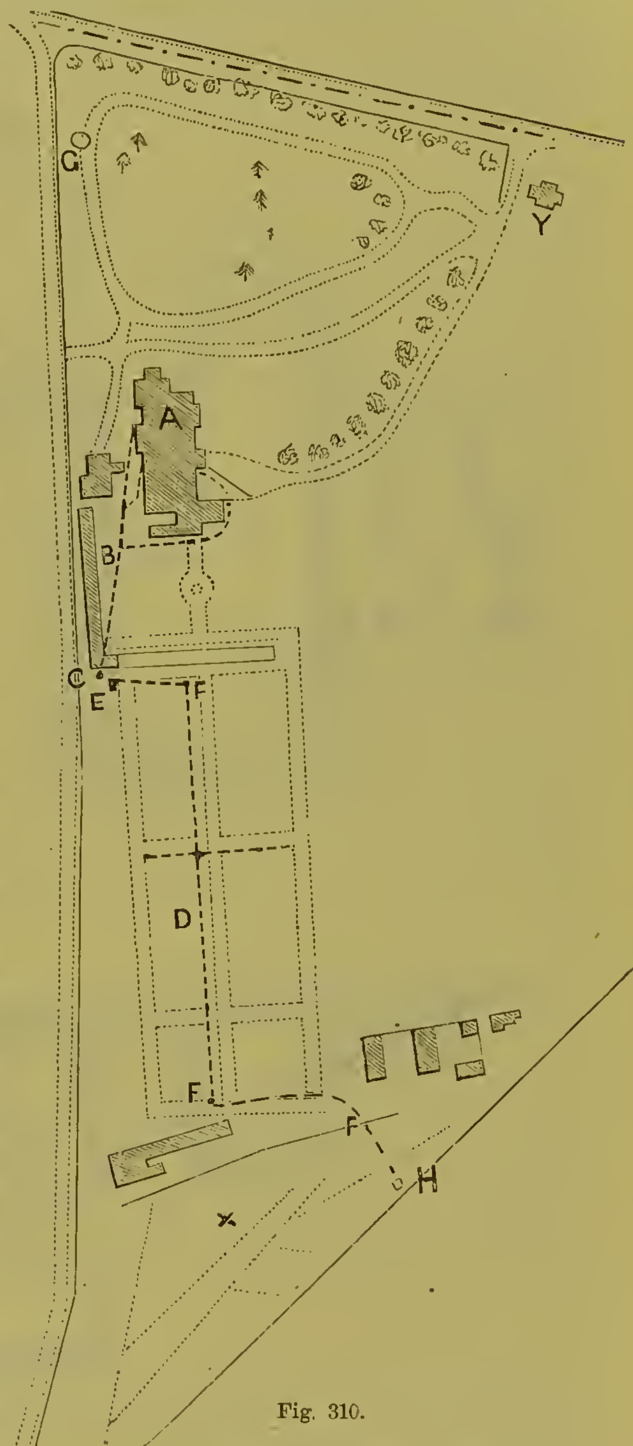

Fig. 310.

At the point R in the tank is placed a movable bucket, into which all the drainage of the house is discharged from the end of the outfall drain. This bucket is perforated, and acts as a strainer to keep back the solid refuse. The bucket is of a size that an ordinary man can lift, and is provided with a chain for that purpose, the contents being removed as often as found necessary, once a day being generally sufficient. The contents of the bucket are mixed with earth, and used in the gardening operations.

The effect of this interception of the solids is almost entirely to prevent the formation of sludge; and what little sludge forms at the bottom of the tank is pumped entirely out every time the tank is emptied, in consequence of the suction-

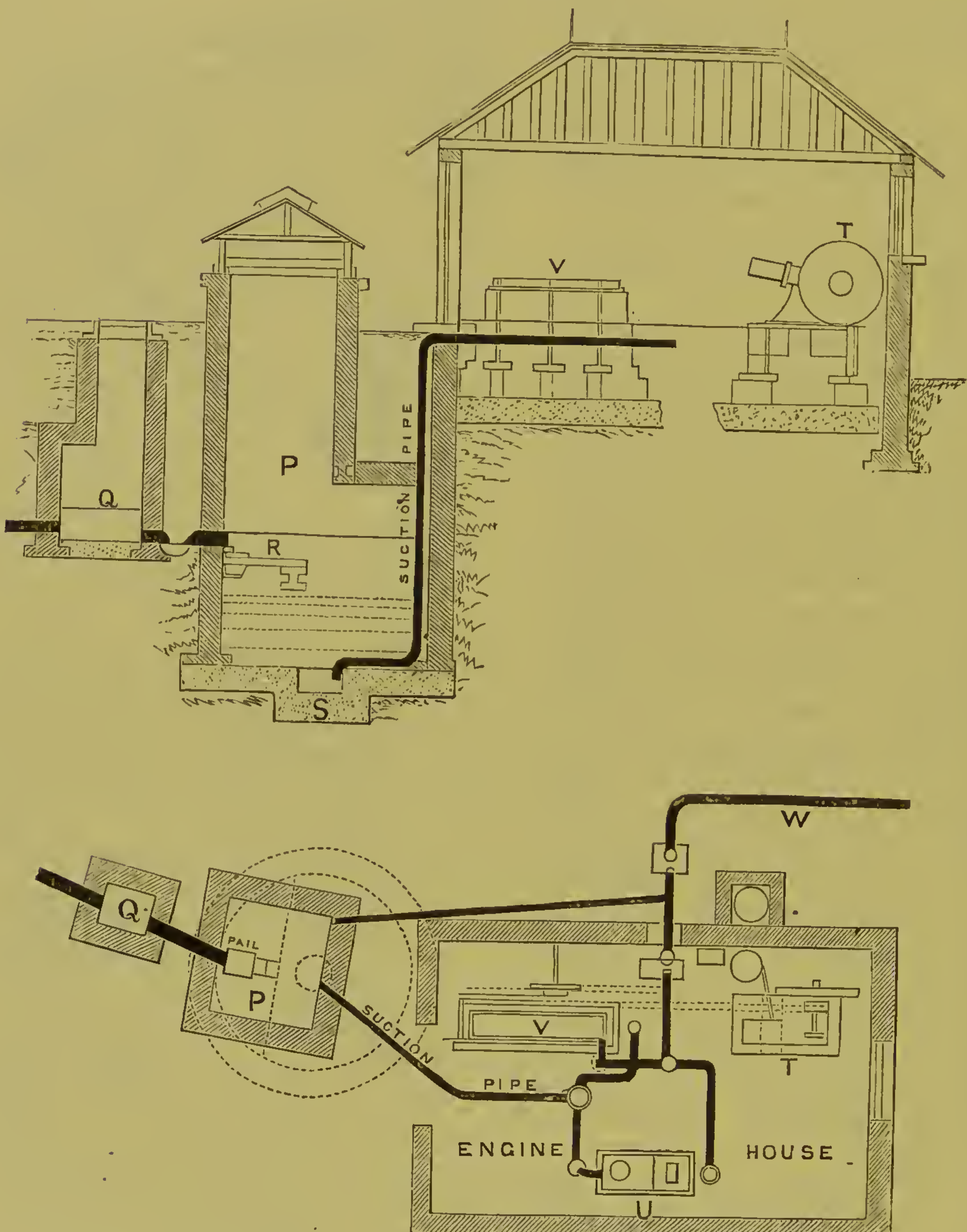

Fig. 311.

pipe dipping into a sump-hole, S, which is constructed below the general level of the bottom of the tank.

From the tank the sewage is lifted by the gas-engine provided at T, and is forced through the iron main W to the point H (Fig. 310) on the summit of the irrigation-ground. The cast-iron main, where it passes through the garden D, Fig. 310, is

provided with stand-pipes, to which a hose can be attached for the purpose of applying sewage to the garden.

The details of the pumping-machinery at V have been carefully worked out; an air-vessel is provided to render the delivery of the sewage constant, and a valve is fixed upon the main to prevent any undue pressure bursting it. The main can also be entirely emptied, if necessary, by means of a special valve. In order to provide against any break-down in the pumping-machinery, an arrangement of hand-power pumps is fixed at U.

The end of the iron main F F F delivers into a small brick chamber at H, Fig. 310, in order to take the wash of the sewage as it is forced out of the main. From this brick chamber the sewage flows gently into the carriers, which are constructed in the simplest possible way, by means of shallow channels or furrows cut into the ground, and from these carriers the sewage flows over the surface of the ground. The irrigation-field is under-drained, as shown by the fine dotted lines upon the sketch, Fig. 310. The lodge at the entrance of the property shown at Y upon Fig. 310 was too far away to be drained into the general system, and this was therefore dealt with in a different way. The dry-earth system was used for the closet, and the slop-water from the sink discharged outside the house into a flush-tank, which delivered into sub-irrigation drains under the garden. The bed-room slops had to be emptied into the flush-tank direct.

An example of sewage-disposal, and one of some interest as occurring frequently in practice, is shown on the sketch, Fig. 312, and is here given as illustrating a similar case to the last described, where the sewage is brought by gravitation to a suitable spot and afterwards lifted by power to some distance and height to ground which it was considered desirable to irrigate with sewage. The system of drainage, as originally arranged, in this case and around the village, was exceedingly dangerous; cesspools and midden pits generally prevailed, and, as the water for drinking-purposes was obtained from shallow wells placed near the cesspools, the wells became in some instances polluted.

The landowner was desirous of adopting some means of altering the existing state of affairs, and the scheme to be described was prepared by Mr. Wallace Peggs, Assoc. Mem. Inst. C.E., to meet the difficulty.

The properties to be dealt with were conveniently situated with regard to drainage, the land falling generally towards the river, where a suitable spot was fixed to which the drains could gravitate near the bridge carrying the turnpike-road over the river. The difficulties of such a small scheme as that under consideration were considerable, for the land available for receiving the sewage was at some distance away beyond the river, and situated upon the slight escarpment shown upon the diagram.

It was not considered desirable to use the land near the river for irrigation on account of its proximity to the mansion, and the portion of ground which could be available was liable to flooding. Moreover, the ground was of a heavy stiff clay, and not suitable for the purpose. The ground chosen for irrigation-purposes was of a very suitable kind, being a poor light gravelly subsoil overlying the chalk.

The drains from the houses, as shown by the dotted lines upon the diagram, were laid out truly in straight lines from point to point, with inspection-manholes at every turn, providing also the necessary ventilation-openings. Each length was

provided with special flushing-arrangements, and the drains were all laid to self-cleansing grades.

All the drainage was eventually carried to the point marked A upon the diagram, crossing under the river near that point and arriving at the tank built to receive it, from which it is to be pumped in the manner as follows:—A small stream of water running alongside, and being parallel for some distance, was,

Fig. 312.

after careful gauging, found to yield sufficient power for working the small turbine which is placed in the building at A. The turbine was arranged to drive the pump which lifts the sewage from the tank and delivers it by a cast iron main to the point marked B on the irrigation-grounds. Arrived at that point the sewage is distributed through carriers of earthenware pipes along the main lines, as shown, and from these into subsidiary carriers, and thence into small furrows in the top soil. The whole area of the irrigation-ground is under control, and each may receive its proper share of sewage by a little attention to the valves and turning-points.

No one should undertake to execute sewage-disposal work, especially irrigation of any kind, except he has satisfied himself of the strata and subsoils and any other matter which influences the proposed works. It is a general practice for engineers to specify what work is intended to be done, but the person who carries it out has

commonly to obtain his own information on any subject which can in any way influence the quotation of a price for the work. As a rule, also, no charges for extra work are allowed in consequence of any misunderstanding of the drawings, the intention being that for the defined sum the work is to be satisfactorily executed—any really extra work, or any less work, being rated at the schedule sent in on the quantities. In work of this kind it is always very desirable to furnish quantities, for, otherwise, the client will often be the loser. It should also be entrusted to an engineer in the first place, if for no other reason than the necessity of furnishing accurate levels coupled with the best advice generally. When this precaution is not taken, it often happens that the works are carried out in a faulty manner, and have even to be executed over again, perhaps on an altered scheme altogether. All surplus earth not required for forming and levelling up the lands, roads, or embankments, and all stone, gravel, clay, sand, or timber, &c., should be reserved by the client and removed to a suitable place, but as a matter of course the contractor is to be free to make use of them as far as they are useful to him on the works. These few remarks are merely thrown out as likely to be useful. The contractor for this kind of work should always agree to a six months' maintenance of his work before he receives his final balance of account.

SEA-DELIVERY OF SEWAGE FROM HOUSES.

It is not an uncommon practice for persons residing near the sea-shore to take their sewage to the nearest cliff or sands, leaving it there entirely to itself, careless as to what amount of nuisance it is creating. Deliveries of this kind can easily be found by tracing the passage of the black silt across the sands when the tide is out, or by watching the detour which pedestrians make in order to avert the smell when nearing such an outfall. Towns are allowed to discharge their sewage into the sea, however, only below the line of low water; but this is a very different thing from turning the sewage of a cluster of houses, for instance, into the sea above high-water mark. In unfrequented haunts the nuisance would be small, but it is very different if the practice be resorted to in the neighbourhood of watering-places, as is frequently the case, for then the sewage will be thrown back upon the shore and contaminate it. Moreover, as has been pointed out, sea-water does not readily oxidise sewage, and when the latter becomes incorporated with the material which forms the beach, the gases evolved therefrom in the summer are dangerous to health. The old bathing-places of many villages have been entirely destroyed by the inconsiderate turning of sewage into the sea, and several cases in point come prominently to my mind, where even the neighbourhood of a mansion has been polluted for want of care in this particular, and coves more and more remote sought in turn, in order to enjoy some freedom from the sea-borne mud and wind-wafted odours.

Leading the sewage of a residence to the sea, or even the overflow of cesspools, then, is one of the clumsiest modes of dealing with effete matter, and recourse should be had to irrigation of some kind. There is almost always a garden where the wastes could be treated in a sensible manner, and the gardener who does not see the advantages which might be gained by a utilisation of such wastes upon his land can have no sense of propriety or economy.

THE CHEMICAL TREATMENT OF SEWAGE.

It sometimes occurs that a building has been erected upon a site which offers no convenience for the removal of the sewage, there being either no sewer to drain into or no land belonging to it, making irrigation out of the question. And it often happens that such a residence and offices have been draining for many years into a running stream, when suddenly notice is given by the authorities to the owner, insisting upon an abatement of its pollution. Under these circumstances, it is likely enough that recourse must be had to some sort of precipitation. There are several methods of effecting the precipitation of sewage, and the removal of its chief polluting ingredients; for instance, the *ordinary* lime process, as used at Bradford; the *Hille* lime process, as in use at Tottenham; the *Scott* lime process, as carried on at Burnley; the A B C, or *native guano* process, as in operation at Aylesbury; and the *Precipitation and Irrigation* process, which is worked by the Rivers' Purification Society at Coventry. The result of this precipitation of sewage is called sludge, and it has various values according to the chemicals employed. Sometimes the sludge resulting from the lime process only is simply carted upon the land, and as the sewage is but partially purified the effluent is hardly fit to be allowed direct entrance into a stream. In General Scott's system at Burnley, the sludge is dried and burnt into clinkers, which produce, when ground, a good hydraulic lime. Col. Jones, V.C., has a plan in operation at Wrexham, by which, after the sludge is dried sufficiently, a manure is produced by mixing twelve parts with seven parts of fine raw bone-meal and one part of sulphate of ammonia. The sludge produced by the A B C process, where the sewage is treated by alum, blood, clay, and charcoal precipitants—in proper proportions—is dried by pressing, heating, and grinding into powder, which finds a ready sale at home and abroad. The sludge at Coventry is air-dried simply, and is valuable for dressing on the land. The effluent water from the tanks in this last instance is the resultant of irrigation as well, and is very pure.

An excellent idea of the values of the various systems of the treatment of sewage by chemical agency will be found in Professor H. Robinson's work on "Sewage-Disposal," and it is evident that much has to be considered before having recourse to precipitation. There is no work extant which treats of the adaptability of chemical treatment to houses—all the recorded systems dealing with towns and cities only.

But examples must be multiplied, and the results carefully analysed, before the treatment can be deliberately recommended. Very few cases, one would think, would occur in which irrigation of one kind or another would be found impossible, in the matter of country houses especially.

CHAPTER LXX.

HOUSE EXAMPLES AND CONCLUSION.

Example of Cottage-drainage—Of the Drainage of a Large Villa—Of the Drainage-arrangements of a Large Mansion—Sundry Hints for Guidance in the matter of House-drainage—Useful Memoranda to Persons concerned with Work of that description.

Before concluding my section it would perhaps serve some useful purpose if I were to furnish an example of buildings showing drainage-arrangements actually carried out, with a few remarks thereon. I will therefore do so, giving three instances, one of a small cottage, one of a large villa, and one of a large mansion. It will be impossible, however, upon any reasonable scale to show the outhouses and other buildings appertaining to the two larger plans which follow, but where it is at all necessary the relationship of these to the main drains will be explained. In no case were brick drains made use of in any way.

It should be borne in mind that in laying down drains, especially soil-drains of any kind, they should be laid down upon straight lines; and whenever a fresh direction is necessary, a manhole should be placed at each diversion, the object being not only to be able to clean out the drain easily when required, but also to afford a line of sight through the drain at each length.

Fig. 313.

At Fig. 277, page 656, I purposely drew an example of a house drained on curved lines, so as to explain what was undesirable in this respect; but I did not complicate it by drawing the desirable lines. It is easy to see, however, that straight and not curved lines were possible there, and I merely mention this because straight lines are always preferable to curved lines, however easy the latter may be. Examples of drains laid down on straight lines will be furnished in the next few pages. It is sometimes allowable to curve a drain which does not remove anything except rain-water to a tank underground.

At Fig. 313 I give the sketch of a small one-storey cottage such as would be inhabited in rural districts, and containing sufficient accommodation for a man and wife and a small family, requiring the use of one bed-room only.

There is a kitchen, a large living-room, and a parents' bed-room, with store and pantry accommodation, and with a side verandah, up the posts of which a shade

could be got by climbing-plants. Nothing could be simpler than the plan of such a cottage.

It might be that this cottage could be placed in proximity to a drain leading to a sewer, in which case the closet at A could be a servant's cleanly wash-out closet, with a double seat, one with an aperture suitable for children. In that case the closet would be disconnected from the drain beyond by means of any of the closet disconnection-traps explained in Chapter LXV. If the wastes of the cottage could be led into a proper drain, then in that case the waste of the kitchen sink at C could be led into a small disconnection-gully, suitable for cottages at D; such a trap as, for instance, the intercepting-gully known as Dean's, and made with lifting silt-pot, such as I have drawn at Fig. 256. The rain-water would likely enough be collected from the down pipes at roof, and led into a tub at E, with a draw-off from it, and a small gully underneath. Such a collection of rain-water would always be useful for washing-purposes, and if a separate small washhouse were attached to the building so much the better, as the wastes could in that case be collected in one of the automatic flushing-tanks described by me (see Fig. 279, for instance), which would, when full, deliver its contents, and so flush out the drain.

Likely enough, however, such a cottage in the country would be erected far away from any drain, and in that case the treatment would be different. Then, very possibly with advantage, the closet A would become an earth or ash closet, the former being preferable, as being more suitable for use in small gardens, such as are always attached to cottages of this description. Then, also, with no regular drain, the kitchen sink would best be delivered into a small flush-tank, which would receive the kitchen liquid wastes; and if there were no small washhouse, and the washing-tub were placed on the sink C, the wastes would deliver all the same into the flushing-tank, which would be placed outside the house at D. When it became necessary to empty the bed-chamber slops, it would by no means be a sanitary practice to empty them down the sink C, despite the access-trap which would be wisely placed there, and these slops should rather be carried down the steps F, and emptied over the grating of the flush-tank at D, which is in the open air. This tank would be ventilated by a small pipe on the roof, so as to remove any possible smell, and the tank would be occasionally cleaned out to keep it in sweet condition.

I have already explained in Chapter LXVIII. how very easily such slops as would here be collected could be utilised by sub-irrigation on a small plot of ground laid out for the purpose, and I am sure that once a cottager became acquainted with the wisdom of such treatment of his wastes, he would never drain into an open ditch, or into garden pools or cesspools. It is very rarely indeed that a garden is situated where there is no running stream into which his effluent water could be led. The main thing to teach a cottager is to avoid draining into an open ditch, where all kinds of wastes lie festering throughout the year, and do not drain away. If recourse must be had to a cesspool, then this receptacle must be built of brick in cement, and made perfectly water-tight, by rendering it with cement inside; and it should be placed as far as it is possible from any well, ventilated in some proper fashion also, with radial overflows made of common agricultural pipo, laid some foot or so underground. It should also have a common pump fixed over it, not only to facilitate emptying it, but to remind the cottager by its very presence that the

contents can be made useful to the land all the year through. If the pump-mouth were fitted with a screw, and the man had a length or two of common hose, he could distribute the sewage very much better.

A cottage or a congregation of cottages treated in the improved methods mentioned above would greatly conduce to better health in country villages, besides teaching the tenants of the houses cleanliness and economy; and it should be the duty of every inspector dealing with such things to see that no dwelling, however small, should be allowed to be inhabited until the wastes were in some way or other

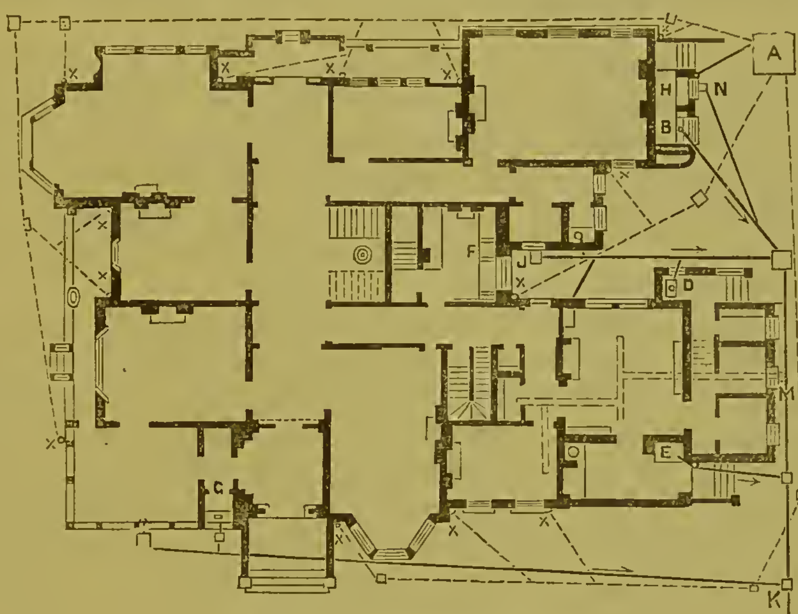

Fig. 314.—Large Surburban Villa.

satisfactorily disposed of. The majority of our country cottages and their surroundings are simply Liliputian pest-places.

I will now furnish an example of the drainage-arrangements of a large villa, designed by me, and erected on one of the northern heights of London. This is shown at Fig. 314.

In this instance it was considered desirable to collect the rain-water from the roofs, and deliver it into a rain-water tank for use in the laundry and gardens. This rain-water tank is shown at A, and the single dotted lines represent the drains, which collect the rain-water from the down pipes, X X, into the tank. None of these rain-water pipes descend inside the house. The drains which remove the closet and sink wastes, &c., are shown by the strong black line, and it will be noticed that none of these drains run inside the house. The plan exhibits the ground floor, the cellars being mostly wine and beer cellars. The closets are situated as under: B being the billiard-room closet, C the house closet, D the servants' closet; and the soil-pipes from the upstairs closet descend on the outside, and are ventilated to above roof. The sinks are as under:—The scullery sink at E, the butler's pantry sink at F, the entrance-hall lavatory at G, and the billiard-room lavatory at H. The wastes of the housemaid's sink, bath, &c., descend in the corner J, where they are disconnected into the open air. Every waste delivered in the open air except simply the soil-pipes, and the disconnection-gullies used for the

bath and sink wastes were of the simplest kind. Beyond the point K, where the two drains make junction, was built a disconnection-chamber with syphon, and open pipe inside the covered-up manhole, such as I have figured in a former chapter. The house-drain had no communication with the drainage from the lodge, as it was possible infectious cases might be present in the latter, to the detriment of the inmates of the house, and both had therefore separate entry into the sewer in the roadway. The laundry was also drained separately into the main drain, because it stood on a lower level. As for the stables and cow-house, the wastes from these were collected into a liquid manure-tank, with pump attached for use in the garden.

The basement or cellars had a separate drain marked by the double dotted line, but this drain was disconnected at a ventilated gully, M, before it passed into the main drain. The disconnecting-gullies round the house are shown at N, J, and P.

As a sewer had been provided for the district in which this house was built, it was not considered desirable to irrigate with the drainage upon the ground in any manner. It is easy, however, to see that this could be very well effected by any of the methods shown in former examples.

I will now give an example of a large mansion in Lincolnshire, the drainage of which I undertook so as to bring it within modern principles. This residence is shown in plan at Fig. 315. The faint continuous lines represent the rain-water, and the bulk of these drains lead to a large rain-water tank situated at R W, having filters before it. The overflow of this tank is by the double faint continuous lines in the direction of X X, where the water passes into a stream. A small water-engine at W W, worked by the waterworks which I erected some two miles distant, raises the rain-water from this tank to a tank at the top of the house for the purpose of ablution. The drains from the house are shown by the darker continuous lines, and are nowhere taken just inside the house, except between R and E, where they are surrounded by concrete.

The basement is drained along the thick dotted line, and this drain became necessary in order to take the water from the hydraulic lift, and also to drain the passages. But this drain does not enter into the main drain until it has been disconnected and rendered safe. The soil-pipes are nine in number, and the whereabouts of their descent is marked S, each pipe being placed outside the house, and duly ventilated to above roof, the closets being all valve-closets, with the exception of the servants' closets, which are wash-out closets, placed at F and M. It will be seen by the position of the various disconnection-chambers, which are marked D, that these chambers are placed as close to the walls of the house as could conveniently be got, a current of fresh air being let into each chamber from a proper inlet. Inspection-chambers are placed at X, wherever this letter is shown, and also at other places. The waste-pipes from the baths, the upstairs and downstairs sinks, all deliver into gullies outside the house. The grease-chamber is placed outside the house at J. The house-drains, after passing through the various disconnection-chambers marked D, converge in the direction of A, B and C, and at some distance below C they meet. At some hundred feet distance from the point where the three make junction the sewage is taken into a straining-chamber, whence the solids are removed daily, the liquids passing into a tank of considerable dimensions, having an annular syphon fixed in it, the action of which is explained, and the whole apparatus drawn in

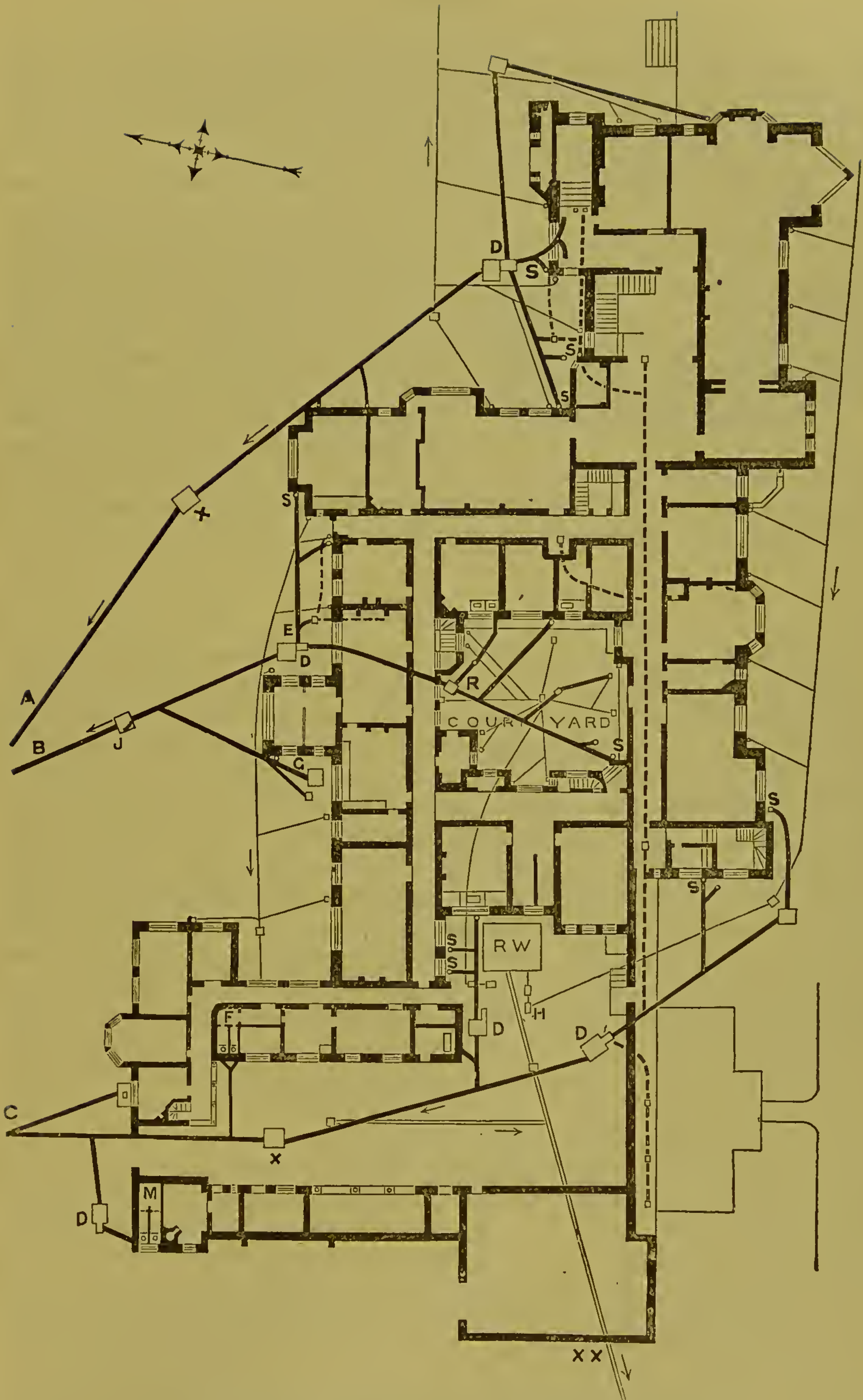

Fig. 315.—Draining of a Large Country Mansion.

section at Fig. 281. When the water has risen up to a certain height in the tank, the syphon is started, and the whole of the contents of the tank are discharged in this instance upon one or more of a series of osier-beds, the effluent being caught in a deep ditch. There is no cesspool anywhere.

The disconnection-chambers, marked D, are all of a pattern similar to that drawn at Fig. 316, and are formed with brick sides well cemented. The action of these air-chambers was described in one of my earlier chapters. It may here be added that

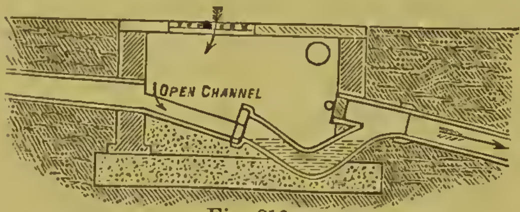

Fig. 316.

between the junction of the drains, where A, B, and C unite, and the large flushing-tank with strainer for solids in front, manholes, acting also as ventilators, were placed from time to time. Hydrants for flushing out the drains were placed wherever the letter H is drawn, and pipes were laid from these points to the disconnection-chambers, the scouring-power of the water being equal to a run through a 4-in. pipe from a distant reservoir some sixty or seventy feet above the plateau on which the house was built.

THE RENTING OF HOUSES.

A person who thinks of taking a house of any kind, in town or country, would do wisely to have the drainage-arrangements examined by some competent authority, in order to see that they are soundly jointed and free from deposits, the soil-pipes properly tight and well ventilated, the sink, bath, lavatory, and other wastes disconnected in the open air, and the wastes or overflows of all cisterns treated in a similar manner. The sinks and lavatories, etc., should also be examined to see if they are properly trapped, for disconnection in the open air is not sufficient, since any effluvium from the trapping-water of a gully, or the smell of any filth in the pipe, will, in the absence of a trap, be often sucked into the room. Floor-traps inside the room should also be removed unless these deliver again into the open yard or area. And previous to entering upon residence, the tenant should make sure that all the cisterns are thoroughly cleaned out, and that no sink or draw-off tap where drinking-water can be drawn is in communication with a cistern which supplies a water-closet.

It is not at all a settled point as to whether a landlord or lessor is obliged to provide the incoming tenant with other than pan-closets; but whether this be so or not, it is advisable that some arrangement should be come to in the way of replacing such closets by valve or other improved conveniences of this kind. The landlord is certainly obliged nowadays to disconnect his sinks and cistern-wastes, and to provide ventilated soil-pipes. The drain must also be sound, and trapped off from the sewer in some manner. In regard to the last precaution, the landlord should be required to show a late or present report from the District Surveyor's office, or Sanitary Authority, stating also that the drainage runs away freely, and that the outfall is cleanly.

With reference to a disconnection between the main drain and the sewer, by which is meant a chamber with open channel pipe, a syphon, fresh-air inlet, and a manhole-cover, the landlord often refuses to go to this expense, and contends that

it is nowhere made compulsory upon him to provide such a contrivance. This is so far true; but rather than the trap between the house-drain and the sewer should take the form of a Mason's or dip-trap, it would be well, if the landlord refuses to provide for a disconnection of some sound kind with an air-inlet, for the incoming tenant to provide one for himself, removing any dip-trap, and seeing that there is no trap at the foot of the soil-pipes to stay the constant ventilation which an air-chamber is meant to provide.

The above general rules should guide every one seeking for a house. If the house has been lately re-drained under proper supervision, and if a certificate has been granted to it by an efficient engineer as being healthworthy, this should mean that all the foregoing rules have been carried out. Even then, however, the cisterns should be cleaned out, the syphon-chamber and air-inlet examined, and the gullies and drain flushed out; and always after painters or decorators have had the run of the basement for a time, the whole of the traps and drains should be examined to see if they are free from the many foreign materials which they are apt carelessly to throw into the drain, by way of some handy sink or yard-trap.

Experience teaches over and over again that, as a rule, it is not wise for an incoming tenant to allow the landlord to "put the drains right for him" before he takes up residence, inasmuch as on too many occasions the remediary work is given to mere jobbing builders, who do not understand the disconnection and ventilation of drains. The wisest plan is for the tenant to employ some competent person to make a report upon the sanitary arrangements of the residence as left by the last tenant, and then to stipulate that certain work must be executed to the satisfaction of his engineer before any agreement or lease is signed. It is not an uncommon occurrence to find a tenant who has entered upon a house being obliged to leave it before he has occupied it for a month, and to be put to the inconvenience of having much work carried out before he can resume occupation, and this at his own expense, with no remedy against his landlord. It is for the interest of lessor and lessee alike that everything should have been put in good order at the first. Cases do occur where, from faulty drainage, a tenant can justifiably refuse to remain in the house, and refuse to pay rent then due and future rent as well; but an invocation of the law in these cases is a very expensive course to take, and the cost of proving that the house was uninhabitable, or, *vice versa*, that it might be regarded as a healthy one, invariably turns out to be moreover a very tedious and doubtful matter, involving the examination of many kinds of witnesses.

USEFUL MEMORANDA.

The following memoranda, taken from several sources, may be taken as fairly reliable, and will be found useful :—

Water.

277·123 cubic inches = 1 gallon.
1 gallon weighs 10 lb., and occupies 0·16 of a cubic foot; 6¼ gallons = 1 cubic foot.
1 cubic foot weighs 62·4 lb.
1 cwt. = 1·8 cubic feet or 11·2 gallons, and 1 ton 35·9 cubic feet or 234 gallons.
1 cubic foot multiplied by 0·557 = 1 cwt. nearly.
1 cubic foot multiplied by 0·028 = 1 ton.

The daily average consumption of water per head is about 8 gallons, and about 25 per cent. more is required in summer than in winter. It is usual to calculate for up to 30 gallons per individual per day.

Sewage.

A velocity of 60 feet per minute will suffice for sewage which almost resembles water, one of 90 feet per minute for strained sewage, and one of 150 feet per minute for ordinary sewage.

One inch in depth of sewage over an acre of land is equal to 101 tons or 22,600 gallons.

Taking all ages and sexes together, the daily amount per head of population is about $2\frac{3}{4}$ ounces of fœcal and 40 ounces of urinary discharges, or a total of about $2\frac{3}{4}$ lb. It is near enough to reckon the solid to the fluid evacuations as 1 to 16.

Measures.

Lineal feet multiplied by ·00019 = miles, and lineal yards multiplied by ·000568 = miles.

Square yards multiplied by ·0002067 = acres.

DEFECTIVE SANITARY APPLIANCES AND ARRANGEMENTS.

By Professor W. H. Corfield, M.A., M.D. (*Oxon.*).

CHAPTER LXXI.

DEFECTS IN DRAINS AND DRAINAGE.

Nature of Defective Sanitation—Faults of Old Drains and Cesspools—Old Traps—Defects in Laying Drain-pipes—Faulty Connections—Ventilating-pipes—Various Defects through which Foul Air may enter a House—Faults in Yard and Sink Drainage—Connection of Water-supply with Soil-pipes.

When refuse organic materials are allowed to accumulate in and about houses, decomposition takes place in them, and foul-smelling substances escape into and contaminate the air, the soil, and the water around.

Under such circumstances deterioration of the health of persons living in houses where this is the case of necessity takes place; and so the general death-rate in towns where the refuse materials of the population are not continuously removed from the houses is high, and is invariably lessened by the more speedy removal of such refuse matters, no matter by what means such removal is carried out.

As young children are more affected by impure air than adults, it is found that in such towns the death-rate of children is especially high.

Since the refuse excretal matters from human beings may, and not unfrequently do, contain poisons of certain specific diseases, the more these refuse matters are retained about the premises, the more likely are such diseases to spread.

The Oriental plague and cholera have always prevailed most in the filthiest places, and on the other hand, in towns where the refuse materials are most speedily removed, "cholera epidemics have been rendered practically harmless."

Enteric or typhoid fever is also a disease, the poison of which is especially spread by means of excremental matters, and it is found that this disease prevails especially in places where excremental matters are collected in and about the habitations, and where the soil and the water in the wells get contaminated by these matters.

It is for this reason that typhoid fever and cholera are more especially prevalent upon pervious soils. People living upon such soils obtain their drinking-water from wells dug near to the houses, and it is plain that if excremental matters are allowed to get into the soil they will find their way into the wells. If then these matters contain the poison of typhoid fever or of cholera, the drinking-water will become contaminated with it, and thus the disease will be spread.

Diphtheria is another disease which is also without doubt propagated by means of foul matters containing the special poison of the disease; but while the poisons of

enteric fever and cholera seem to be especially conveyed by means of foul water, though no doubt occasionally also by foul air, the poison of diphtheria, on the other hand, is especially conveyed by foul air, but is also certainly in some instances conveyed to human beings through the medium of foul drinking-water.

Diarrhœa, which produces so large a number of deaths in the summer, especially in our large towns, is also produced to a very great extent by the drinking of foul water at a temperature above 60° Fahrenheit; and is no doubt produced by the decomposition of organic matters contained in such water, more especially by decomposing excremental matters.

Relaxed and ulcerated sore throats are also very frequently caused by living in atmospheres contaminated with the results of fœcal decomposition. An outbreak of sore throat in a house is a very frequent sign of defective sanitary arrangements, by which foul matters are allowed to accumulate, and the result of their decomposition to poison the air; a severe form of pneumonia has also been not infrequently traced to a similar cause.

Thus we see that it is of the greatest possible importance for the health of the community that foul refuse matters should be removed continuously and speedily from the vicinity of habitations. This, necessary everywhere, is especially necessary in large towns where so many thousands of people are congregated together upon comparatively small spaces, where, therefore, the accumulation of foul refuse matters is liable to be so much greater on a given area than among more scattered populations, and where, too, other unsanitary conditions of necessity exist to a greater or less extent, and are aggravated by the unnecessary presence of foul organic matters in a state of decomposition.

Defective sanitary appliances and arrangements are, therefore, those which allow of the retention and accumulation of foul refuse matters in and about the houses; and sanitary arrangements are the more perfect the more completely they allow of the speedy and continuous removal of such refuse matters, and the more they prevent any accumulation of such matters, however small.

It will, therefore, be well to learn the defects which are usually found in the drains and sanitary fittings of modern houses. Comparatively few people have the opportunity of building houses for themselves, the majority being obliged to take possession of those which are as perfect, or rather as imperfect, in these respects as most houses which are built at the present time.

The knowledge which it is important to possess should enable the tenant to understand the difficulties with which he will have to contend, if his house is to be so altered as to meet all the requirements of health. As the doctor knows where to look for disease, the householder should know where defects are likely to be found, and by appreciating the character of the evil, will be able to understand the steps which must be taken to put the house into a thoroughly habitable condition.

DRAINS.

Whatever system of removal be adopted for the solid refuse matters, a large amount of foul water must be disposed of in all households, and so channels, or pipes, for the removal of this foul water are necessary in all cases. These are commonly called house-drains, or, more shortly, drains, though they would be more

appropriately denominated house-sewers; as by a drain is strictly meant a channel for the removal of surplus water from the surface or subsoil, and by a sewer is meant a channel for the removal of foul water from dwellings. Popularly, however, the term sewer is restricted to the larger pipes, or channels, by which the foul water from a number of houses is removed, and pipes belonging to a single house are called drains. This is the case because, in the first instance, these channels were made for the removal of surplus surface-water, and it was only secondarily that they came into use for the removal of refuse matters from houses. This being so, they were only made of pervious materials, so that the water could easily get into them, whether from the surface or from the soil beneath. If water could get into them, it is clear that, under certain circumstances—as, for instance, if they got choked up—water could find its way out of them into the soil around; and as these drains were made, in the great majority of instances—especially in large towns—to run underneath the basements of houses, and often in close proximity to wells, the foul water found its way through them, and contaminated the soil under the houses, and the water of the wells.

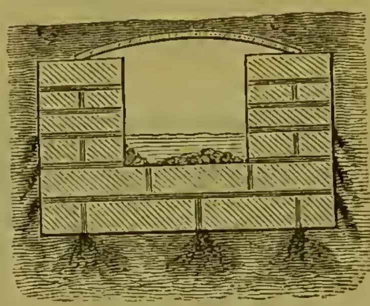

Fig. 317.—Rectangular Brick Drain with Tile Cover, leaking into Soil around.

Such drains were made, and are still often found under old houses, of bricks set in mortar without any cement, either between the bricks or lining the interior of the drain, of rectangular section, so that there was the greatest amount of friction and the greatest likelihood of deposit occurring. Sometimes the top of the drain was covered with slabs of stone, at others with half-tiles, forming a sort of rude arch (Fig. 317). Not only were drains so constructed pervious to water at first, but they became more so as time went on. The mortar was washed out of the joints, so that in old drains of this kind the bricks can frequently be easily pulled out with the hand. But rats worked their way through them into the houses, carrying foul matters, and perhaps the poisons of certain communicable diseases, with them to various parts of the houses, and especially to the food in the larder, or store-room; and, moreover, foul air from the drains entered the houses by the holes made by the rats, and rendered the air impure (Fig. 318).

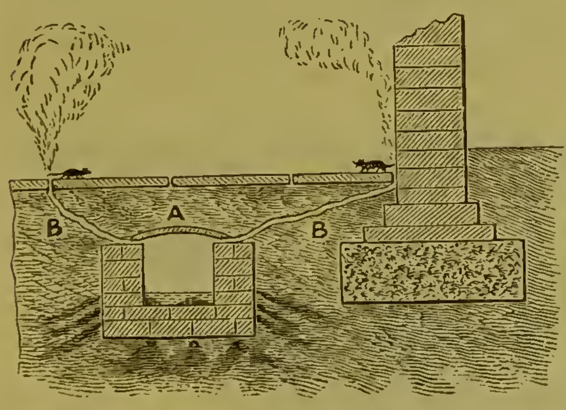

Fig. 318.—Rat-runs from Defective Drain into Basement, Foul Air escaping into House.

Not only were these brick drains porous, but they were far too large for the purpose for which they were required; and, especially as they frequently had but a slight fall, the amount of water passing through them was not sufficient to keep them clear of deposit. In order to prevent such drains being a nuisance to the persons inhabiting the houses, it was sometimes the practice to cover a large part or the whole of the basement of the house with a layer of concrete three or four inches thick.

By this means some of the evil effects were obviated, but it not unfrequently happened that a serious nuisance to neighbouring houses was caused in this way. In one instance which came under my notice some years ago, there had been on several occasions cases of disease that appeared to be due to foul air, in a house where the sanitary arrangements had been carefully attended to. On account of the fact that smells were observed to issue from the loose joints of the pavement in the basement—not near the drain of the house in question, but on the side remote from it, and against a neighbouring house—the paving was taken up, when it was found that the rats had made a channel from the drains of the neighbouring house into the basement of the house in question, under the hearthstone of the kitchen grate, no doubt attracted by the warmth, and also by finding that it was the easiest way out of the drain into one of the houses (Fig. 319). Under this hearthstone were more than a score of dead rats, in all conditions of decay, from dry skeletons to recent corpses; and the reason they had found this to be the easiest way was that the owners of the next house, having experienced a considerable nuisance from their drains, had had them and the whole basement covered with three or four inches of concrete. As they had no nuisance in their own house, it was with the greatest difficulty that they could be persuaded that their drain could produce a nuisance anywhere else, or that there was any necessity for them to have anything done to it. I should add that the drain in question was not only most imperfectly constructed, but communicated directly with the street sewer, so that the rats had opened a connection between the interior of the house, in which the owner had had everything done that was possible to put his house in a wholesome condition, and the main sewers of London.

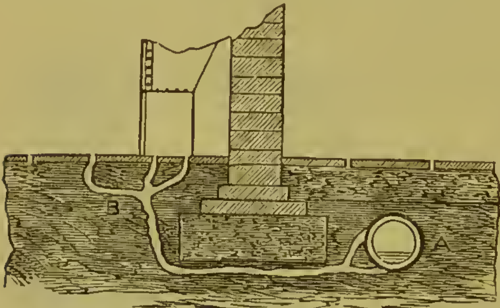

Fig. 319.—Rat-run from Defective Drain of one House into Basement of another.
A, Defective Drain; B, Rat-run. N.B.—Over A is a layer of concrete.

Since such brick and tile constructions were originally meant to carry off the surplus drainage-water of the town, they were naturally taken to the nearest watercourse; and so, when refuse matters from houses began to be turned into them, it was thought desirable that some means should be adopted for preventing the more solid parts of such refuse from getting into the rivers, and it was usually the practice to have one or more pits, or cesspools, connected with the drainage-arrangements of a house. These cesspools were usually constructed with as little care, as regards their being pervious or impervious to water, as the drains themselves. Indeed, in some instances they were deliberately made as pervious as possible—their brick

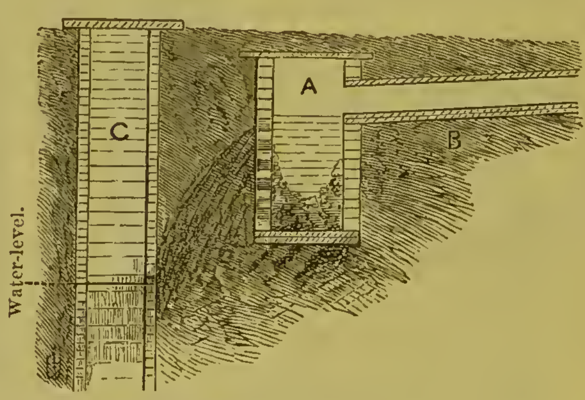

Fig. 320.—Cesspool leaking into Soil, and contaminating the Water in Well.
A, Cesspool; B, Drain; C, Well.

walls not even being joined with mortar—in order that as much water, or rather as much foul water as possible should percolate out of them.

In one town it was the practice in constructing a cesspool to dig down to a "spring," in which case the cesspool needed no other outlet, and never required to be emptied; a stone was put over the top of it, and it was sealed up "for ever"—the acme of all that could be done in removing foul matters from houses being considered to be reached by this method. These cesspools were placed either actually under the house, or in the immediate vicinity, and frequently—I might almost say generally—at a short distance from the well which supplied the family with drinking-water (Fig. 320). The well, of course, collecting water from the soil around, was supplied very largely by the foul water that percolated from the pervious drains and cesspools under or near the house.

It is to this "circular system" of water-supply, as it has been termed, that we owe the fact that enteric, or typhoid fever, and cholera—diseases the poisons of which are chiefly spread by means of impure drinking-water—are far more prevalent upon pervious soils, so healthy in other respects, than upon impervious ones, which do not permit so readily of soakage through them, and in which, moreover, wells are not so frequently dug, partly on account of the difficulty of getting water, and partly because it is not so clear and sparkling and pleasant to the taste as the water from gravels or sands, so that the drinking-water has to be procured from sources which are less likely to be contaminated by soakage from cesspools and drains.

As these porous drains offered little obstacle to the passage of foul air from the sewers or cesspools into the houses, a contrivance was devised for preventing, at any rate, the rush of a current of air up the drain. This consisted in making a pit, or receptacle, in the course of the drain, before it reached the sewer or cesspool, and fixing a slab of stone or slate right across the drain, over the middle of this pit, and dipping two or three inches into the water that, of course, always remained in it up to the level of the outlet leading to the sewer or cesspool. This construction was known as the dip-stone trap, but, from the fact that it was frequently made of considerable size, and often some feet deep, it was, and is still, known in some parts of the country as the cesspool, and acted as such by retaining a considerable quantity of solid filth. Indeed, I have seen cesspools that had evidently been originally constructed as such, with a large dip-stone in them, for the purpose of preventing foul air from the sewers getting into the house-drain. More care was usually taken in the construction of the dip-stone trap than in that of the drain, as it was necessary that the former should hold water, in order that its purpose might be effected, and so it was frequently lined with a coating of cement. The drains and cesspools were not provided with any means of ventilation, unless accidentally by means of rain-water pipes, or openings from the surface leading into them and insufficiently trapped—that is, not properly protected against the escape of foul air from them into the house or its vicinity—

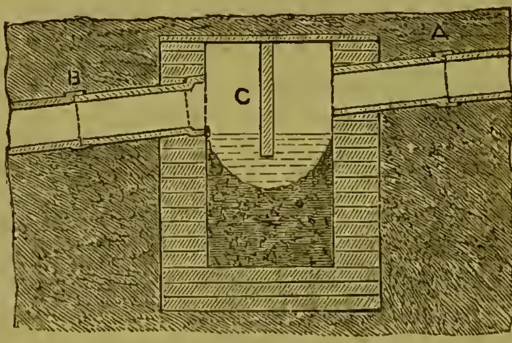

Fig. 321.—Deep Dip-stone Trap, with accumulation of filth in it.

A, Drain entering Trap; B, Drain leaving Trap; C, Dip-stone.

and so the foul air found its way into the houses, both through the connections made with the drains from various parts of the house, and through the soil itself.

From all this it will be seen that it is necessary for house-drains to be impervious to water, and this effect is attained by making them of glazed stoneware pipes, with socketed ends, properly jointed, or in some instances iron pipes are used. Stoneware pipe drains are, however, frequently laid so as to prove a source of danger. Sometimes they are laid with little or no fall, so that the solid matters accumulate in them, and gradually choke them up. This may happen because the main sewer, into which they have to be taken, is not low enough to allow of a fall in the house-drains; but it frequently happens when the sewer is quite low enough, by the trench in which the drain is laid being dug too shallow, except close to the sewer, in order to save the small expense of digging a little deeper throughout the length of the drain. Thus the drain is nearly flat throughout the greater part of its length, and falls with a steep incline into the sewer.

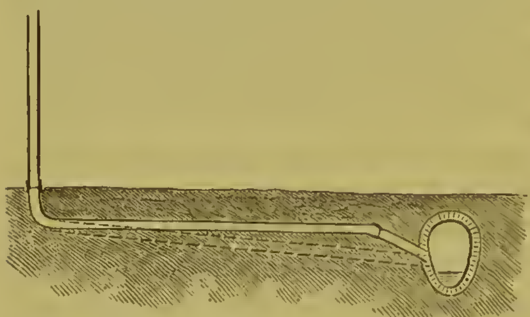

Fig. 322.—Drain laid level, with Sharp Fall near Sewer, instead of with Regular Fall as shown by dotted lines.

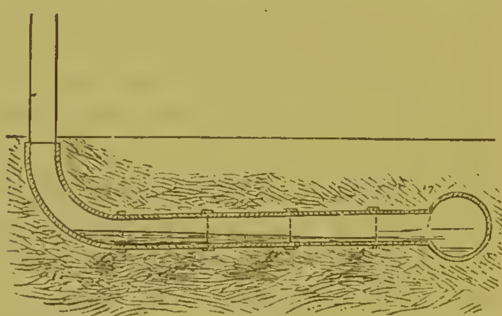

Fig. 323.—Branch Drain from Down-pipe with Fall the wrong way: Accumulation in Drain, Foul Water leaking through Defective Joints.

(Fig. 322.) But things may be worse than this; and not unfrequently branch drains, at any rate, are laid with a fall in the opposite direction to that in which the water is intended to run (Fig. 323). Again, the pipes that are used are frequently too large, because, having been accustomed to build brick drains of eighteen inches or more in diameter, the builders can with difficulty be got to understand that a pipe nine inches in diameter is unnecessarily large for the drainage of a house, and that six-inch, or even four-inch pipes are quite sufficient. Large drains cannot be flushed by the quantity of water that is discharged from an ordinary dwelling-house, whereas small ones can. The amount of water that will suffice to keep a four, or even a six-inch pipe drain quite clear of deposit will not do so for a nine-inch pipe drain laid at the same incline (Fig. 324).

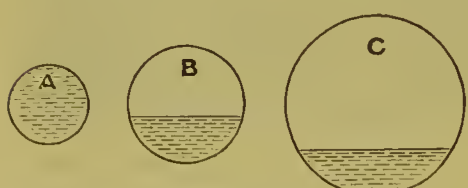

Fig. 324.—A, Section of Four-inch Pipe running full. B, Section of Six-inch Pipe, and C, Section of Nine-inch Pipe, with the same quantity of Water running through them that suffices to fill the Four-inch Pipe.

I have said that the pipes should be properly jointed. There are a variety of ways in which pipes may be and are improperly jointed. One is, when the pipes are simply fitted into the sockets of one another, without any joining-material being used at all, or, as it is technically termed, "laid dry" (Fig. 325). In this case, of course, it is impossible that the drain should be water-tight, and foul water continually leaks into the ground around the drain. Sometimes clay is

used as a material for packing the joints, on the ground that if a settlement occurs, the pipes will not be broken, as the joints will yield a little. This is a very bad argument, as it supposes that drains are laid—as they ought not to be—in such a manner that a settlement can take place. If this is the case, it is quite clear that irregularities will be produced in the floor of the drain, deposits will be formed,

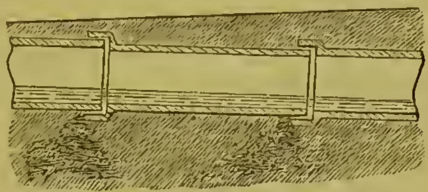

Fig. 325—Stoneware Pipes "laid dry."

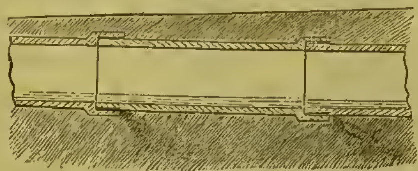

Fig. 326.—Stoneware Pipes laid the wrong way.

and, moreover, the joints which have "given" a little will necessarily leak. Clay is apt to be washed out of the joints in time, and this is especially the case if, as in an instance that came before me some time ago, the pipes are all laid the wrong way, so that the sockets point towards the outfall instead of towards the head of the drain (Fig. 326). In this instance, the clay with which the sockets had been packed was all washed out. The water flowed out through the open joints, and solid matters were deposited in it, until it was completely blocked up.

With cement, on the other hand, water-tight joints can be made which will last perfect for a very long time indeed; but they require to be made with considerable care, or pieces of cement may project into the interior of the drain (Fig. 327), causing irregularities in its floor, and serving as obstructions against which accumulations of filth form, and even if they do not ultimately block up the drain, by their decomposition continually produce foul air. In order to obviate these difficulties, Stanford's joint, already referred to (page 616), has been devised. In this the ends of the pipes and the interiors of the sockets are lined with a preparation, the surface of which is bevelled off in such a manner that the end of one pipe fits tightly into the socket of another. No cement or luting of any kind is required; the ends of the pipe are merely greased and pushed into the sockets. In this way a water-tight drain can be constructed; but it is quite clear that these pipes can be laid—if the work is done carelessly—so that the drain shall not be water-tight at all. It is not an unfrequent thing to find bends in drains, made by fitting the straight pipes together improperly, so that the pipes lie at an angle to one another, and not in a straight line, as they should (Fig. 328). This is done by putting the end of one pipe farther into the socket on one side of it than on the other, and is not unfrequently done to such an extent that one side of the pipe does not enter the socket at all, and a knife or even a finger may be put into the drain between the end of one pipe and the socket of the next.

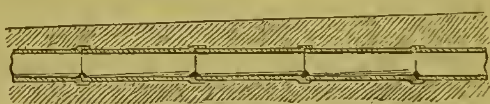

Fig. 327.—Stoneware Drain with Cement Joints improperly made.

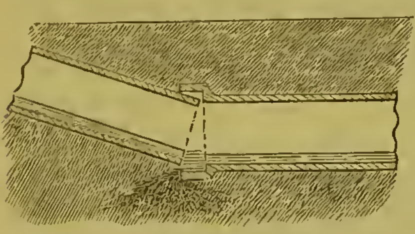

Fig. 328.—Straight Pipes used instead of "Bends."

Pipes are made with various curves, and these, which are technically called

bends, should always be used where it is necessary to depart from the straight line.

The junction and branch drains are frequently made by cutting a hole in one of the main pipes, fitting the branch pipe in, and making good (?) with bits of slate or tile and cement (Fig. 330). Such patchwork jobs are seldom water-tight for any length of time, and there is generally a projection into the drain of the branch pipe, which causes an obstacle to the flow in it; and, moreover, nothing is saved by making junctions in this way, as various kinds of junctions are now made in stoneware, and they are far less trouble to lay than it is to make such a patchwork joint as has just been described.

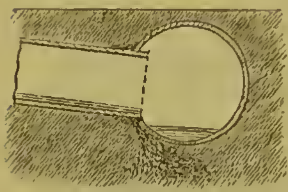

Fig. 329.—Branch Stoneware Drain connected to Main through Hole cut in the Pipe, instead of with socketed Junction.

The junctions should always be laid so that the water running from the branch drains will run into the main in the direction in which it is required to go, and not at right angles to the main drain, and still less in the opposite direction to that in which the water flows in it, and this for obvious reasons. That the mention of this is not unnecessary will be seen in a moment. When it is required to diminish the size of a drain, as in passing from a six-inch pipe to a four-inch pipe, a pipe called a diminishing pipe should be used. This pipe, for the instance just mentioned, would be six inches in diameter on the larger end, and would have a socket for the four-inch pipe at the smaller end. But drains are frequently diminished or increased in size in other ways; that is to say, by making imperfect joints of some kind or another. One most curious instance of this I have lately seen, and it is shown in the accompanying sketch (Fig. 330). Six-inch drains had been laid. The upper part of one of them was finished off with four-inch pipes, but as I suppose the builder had no diminishing-pipe, he conceived the extraordinary idea of continuing from the six to the four-inch pipes by inserting the *socket end* of the four-inch pipe into the last socket of the six-inch pipe of the drain, and then continued the four-inch drain by pipes all laid the wrong way. In one place a junction had to be made to receive the discharge from a gully into which the waste-pipe of a sink was taken. This junction being, like the rest of the pipes, laid the wrong way, the water from the sink had to run in the wrong direction into the drain; for the junction should, of course, always be made so that the water coming in by the branch runs in the same direction as that in the main drain.

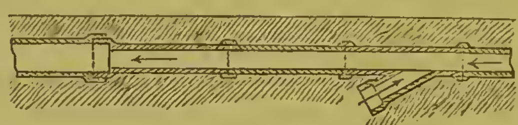

Fig. 330.—Plan of Six-inch Stoneware Drain reduced to Four-inch, by laying the Four-inch Pipe the wrong way, instead of using a Diminishing Pipe. Junction from Gully taking Water into the Drain in the opposite direction to the Outflow.

It is a great mistake in drainage-arrangements to have the drains laid underneath the basements of houses at all if they can be placed outside; but whether inside or outside of houses, drains should be water-tight, and they should be tested by blocking up the lower end, filling them with water, and observing the level to see if the drain remains full.

CONNECTION WITH MAIN SEWER OR CESSPOOL.

In some instances the drain is positively unconnected with the main sewer at all, and of course soon gets stopped up. In others, it is connected with an old sewer which has been blocked up at both ends perhaps for years, but is not full, and continually leaks into the soil around. In this case, a kind of closed cesspool is formed, and the sewage may run away from the houses for years without the state of things being found out; or an old sewer may be blocked up purposely, a new one being laid without all the house-drains being connected with it; but these are, of course, somewhat exceptional instances. Just as was the case with the old brick drains, so it frequently happens with pipe drains, that they are connected directly with the main sewers or cesspools, without any obstruction to the passage of air from the latter up into the house-drains, or with at most a swinging iron flap, which serves to keep rats out of the house-drains as long as it is in working order (Fig. 331).

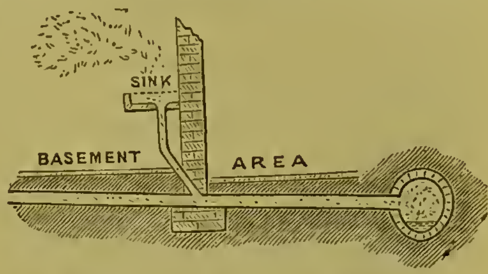

Fig. 331.—House-drain directly connected with Main Sewer; Sink-waste untrapped, and directly connected with House-drain; Air from Sewer escaping into the House.

In some places this is the plan that is deliberately adopted, and no form of water-trap is placed upon the house-drain before it reaches the main sewer or cesspool; the theory being that if the main sewers or cesspools are thoroughly well ventilated, it is better to have no obstruction to the flow of sewage from the houses into them. This plan, however, must be regarded as a defective one, as it is not desirable that the air from main sewers or cesspools, however well ventilated they may be, should be allowed to get into the house-drains at all. Cesspools, of necessity, contain a large quantity of decomposing filth, and the air passing from them is foul, while the air of main sewers, although in many instances very slightly offensive, is liable at any time to contain the poisons of specific diseases, and it is therefore clearly desirable that means should be taken to prevent its entering the drains of houses. This is done by placing a water-trap of some form or another upon the house-drain before it reaches the main sewer or cesspool.

The dip-stone trap, which has already been described, is frequently used, even with pipe-drains; but it is very objectionable, as it retains a large quantity of foul matters, which decompose, and render the air in the drain continually impure. It has been improved by making it smaller, so that it is only as wide as the drain, by giving it a steep slope on the side next the house, and a gradual slope into the exit, by sloping the dip-stone in the direction of the water, and by rounding off the bottom of the trap, so that there are no corners for foul matters to collect; and a still further improvement consists in placing a U-shaped stoneware bend, commonly called a syphon-trap, upon the course of the pipe drain. This bend, being of the same diameter as the drain, holds a much smaller quantity of water than any of the forms of dip-stone trap, and sediment is much less likely to accumulate in it.

But even in the use of these traps there are several things to be guarded against which must now be pointed out. As I have already said, nine-inch pipes were formerly laid, and are still very largely used for house-drains, and so, of course,

nine-inch U-traps were placed upon them. Now, the water from an ordinary house will not keep a nine-inch trap clear of sediment, so a deposit accumulates in it, and ultimately it becomes stopped, the drains get full of water, and the yard or basement of the house is flooded. In order to get at the trap and remove the obstruction without breaking a pipe, these traps were made with a vertical pipe rising from the lowest part of the bend, and this pipe was carried up to near the surface of the ground, a plug being placed in the top of it, which could be easily removed, so that the contents of the trap could be stirred up, or it could be forced by a plunger. But, as will be seen from Fig. 332, this upright pipe must always contain water up to the level of the outlet of the trap, and so floating matters coming down the

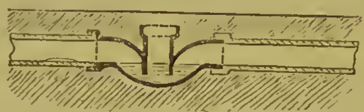

Fig. 332.—Bad Form of U-trap (Syphon-trap) with Inspection-arm in centre.

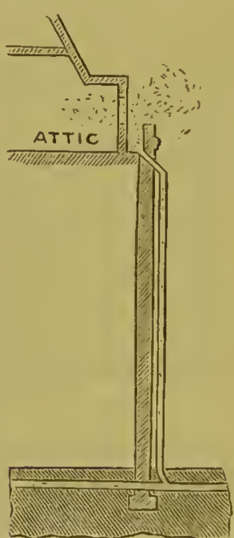

Fig. 333.—Rain-water Pipe directly connected with Drain, and ventilating it under Attic Window.

Fig. 334.—Ventilating-pipe ending near neighbouring Windows.

drain and passing into the U-trap rise up into the water in the vertical pipe, and there remain for a considerable time, not being removed by anything but a very large flush of water; so that they help to keep the water in the trap foul. It is therefore necessary to have some other way of getting at the trap. Although a water-trap will prevent a rush of foul air from the main sewer, or cesspool, into the house-drain, many gases contained in such air, being soluble in water, are absorbed by the water at one end of the trap, and come out into the air in the house-drain at the other end; so that even with a water-trap on the house-drain, the air in the latter is foul, and it was soon found that if no means of escape were provided for it, it would find a means of escaping for itself, through the connections between the house and the drain, and even, as will be seen farther on, through the substance of the lead pipes connected with the drain. This led to means being provided for the escape of foul air from the drains by means of pipes, which

should of course be made to end in such positions that the air coming out at them will not produce a nuisance. In some instances, however, the remedy has been made as bad, if not worse, than the defect. Frequently, for instance, rain-water pipes, starting behind a parapet close to the bed-room windows of the top floor, passing with loose joints close to the windows of the house, connected by small branches with balconies and conservatories, are allowed to pass directly into the drain, thus giving out foul air in close proximity to the windows of the house; or ventilating-pipes are allowed to end within a short distance of windows, so that the air that comes out of them is liable to be blown into the house, or into neighbouring houses (Figs. 333 and 334).

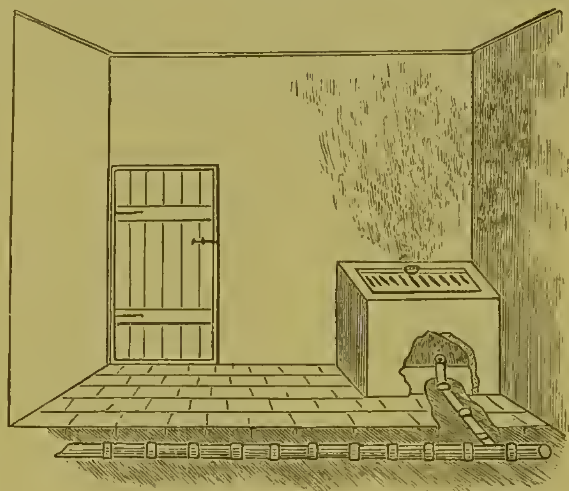

Fig. 335.—Drain connected with Air-inlet in Cellar.

I have seen a ventilating-pipe, or rather shaft, constructed with bricks and mortar, and connected with the drains, standing up in the floor of a wine-cellar, with what is called a "hit and miss" ventilator on the top of it, so that the air from the drain could be turned on or off as was considered most desirable. This was no doubt originally intended to ventilate the space under the floors, but, during some alteration to the drains, the channels which led from it being observed and thought to be drains, had been connected with the house-drain (Fig. 335). In another instance which came under my notice the drain of the house was ventilated at its upper end—the proper place for a ventilation-pipe—directly into the scullery by a pipe ending just under the ceiling. This was brought to pass in the manner shown in Fig. 336. A pipe was placed down an angle of the scullery, to take the rain-water from the flat above into the drain. It was necessary to have a bend of some kind at the top of this pipe. The bend found to be most convenient, or the one which happened to be at hand, was a Y-shaped junction. This was accordingly put in at the top—one branch of the Y connected with the head which received the rain on the outside, and the other one left wide open in the scullery. It was, no doubt, intended that the latter should have been closed up, but this had never been done, and the air in the scullery at the time of inspection was in the most pestilential condition. I have seen a drain actually ventilated by the open head of a rain-water pipe inside a house, and receiving the water by means of gutters from the roof (Fig. 337). I have seen, too, the ventilating-pipe of a drain made to end inside a shaft which was intended for the exit of air from the water-closet, but which, in reality,

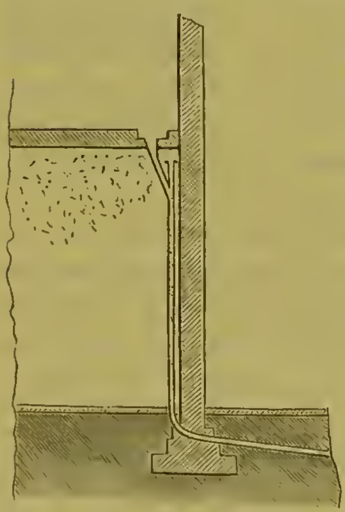

Fig. 336.—Rain-water Pipe at Head of Drain, ventilating it into Scullery.

acted far more often as an entrance-shaft than as an exit, in which case the air escaping from the ventilator was, of course, all brought down into the house.

Drains are frequently ventilated—especially in old houses—by the overflow-pipes of the cisterns. I select the following typical example (Fig. 338). In a large house, where there were old brick drains, partly filled with foul sediment, and so pervious that most of the water that went into them leaked out into the soil around, directly connected with the main sewer, and bored through by rats in various directions, the main drinking-water cistern, in the basement, had a large trumpet-shaped standing waste-pipe in it, about three inches wide at the top, and two at the bottom, connected directly by a 2-inch pipe with the drain. This was, and had been for years, the passage by which foul air found its escape into the house, and attention was only called to it when a death from typhoid fever took place. In another instance, where the waste-pipe of a cistern in a water-closet passed directly into the house-drain, which itself was connected directly with a cesspool, a nuisance had evidently been caused in the house, by this method of ventilating the drains into it, and the device shown in Figs. 339, 340, was resorted to for the purpose of obviating the nuisance. A zinc pipe was placed over the top of the waste-pipe of the cistern, commencing by a funnel-shaped piece, larger than the head of the waste-pipe, and dipping half an inch into the water in the cistern when the latter was full—the zinc pipe itself being carried up through the roof into the open air. The idea evidently was to conduct the foul air from the drain out into the open air, but it is clear that this could only be the case when the cistern was full of water, and as soon as a little water was drawn out of it the funnel-shaped piece of zinc no longer dipped into the water, and there was a free passage for the foul air into the house. This is an example of the way in which people are apt to resort to imperfect measures.

Fig. 337. — Rain-water Pipe open under Ceiling, and ventilating Drain into House.

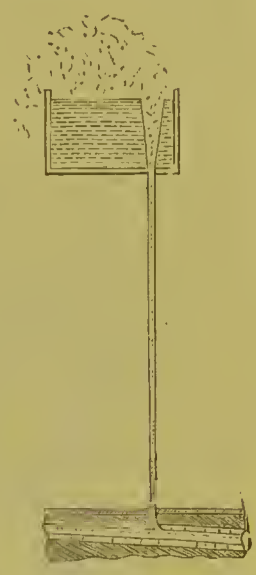

Fig. 338.—Waste-pipe of Drinking-water Cistern, directly connected with the Drain and ventilating it.

The ventilators of a drain should be as large as the branches they start from, and should be at the highest point of those branches; as the branches are usually 4-inch pipes, the ventilators should be four inches in diameter, and they should be carried up above the ridge of the roof, and well out of the way of dormer windows and skylights. Only comparatively recently, a well-laid water-tight drain, with a U-trap on it to prevent the entrance of foul air, and a sufficiently large ventilating-pipe, or pipes, was considered, so far as the drain itself was concerned, to be perfect from a sanitary point of view; no foul air could accumulate in it, on account of the large ventilating-pipes, and the air that was in it was frequently displaced by the discharge of water, &c., at various points into it.

But it has been found that this is by no means a perfect arrangement. The air in such drains, and in the pipes connected with them, is always foul, and nearly stagnant, except in the cases where there happen to be two or three ventilating-pipes, when a current of air may be established down one or more and up the rest, especially if they end at different levels, and so a movement of air be effected in the drain. This being observed, it became at one time, and is still in some places and by some architects, the practice to place a ventilating-pipe (taken up above the roof) at the lower end of the drain between the house and the U-trap, the idea being that air will enter by this pipe and escape by the ventilating-pipes at the highest points of the drain; and so far as ventilation is concerned, this plan will, no doubt, work in the majority of cases more or less efficiently, but it affords no means of getting at the drain or at the U-trap, and must for this reason be considered to be a deficient arrangement.

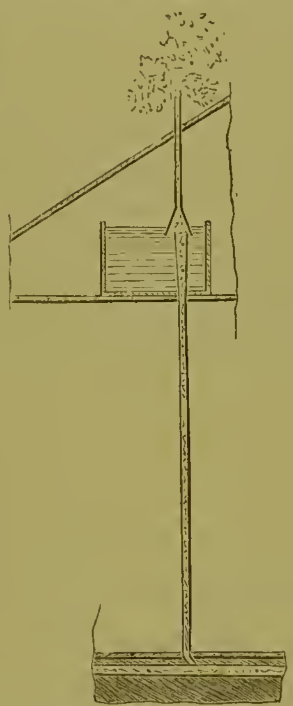

Fig. 339. — Ventilating-pipe over Waste-pipe of Cistern, taking Sewer-air through Roof when Cistern is full.

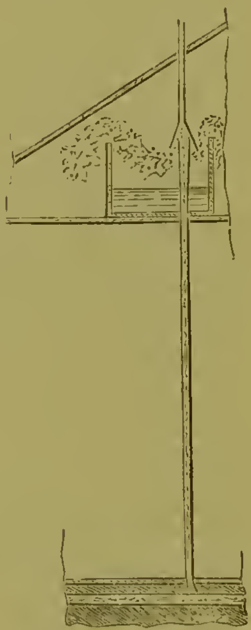

Fig. 340.—Same arrangement with Cistern partly empty, and Sewer-air escaping into House.

It thus gradually came to be recognised that for the proper ventilation of drains it was necessary to have an inlet or inlets for air, as well as an outlet or outlets, and it soon came to be seen that the lower the level at which the inlet was placed, the more likely was it to act continually as an inlet for air. So openings were boldly made into the drain itself, on the house side of the trap, from the level of the ground or thereabouts, and it was found to the astonishment of many that, provided there were no places in connection with the drain where actual lodgment of foul matters could take place, such openings prove no nuisance whatever. This point having been reached, a variety of "disconnecting-traps" were devised, in all of which there is an inlet for fresh air to the drain on the house side of the trap, and in one of which—the Edinburgh air-chamber disconnecting-trap—there is a long open channel interposed between the U-trap and the house-drain. Most of these traps, however, while affording an inlet for fresh air, do not afford a sufficient means of getting at the drain and at the U-trap at any time. Neither, with the exception of the one just mentioned, is the inlet of air as large as is desirable.

Hence the practice, which has been described in preceding pages, of building a manhole or air-chamber in brickwork on the course of the drain, carrying the drain through the bottom of it, as first suggested by Mr. Rogers Field, by means of channel-pipes; and fixing the syphon or U-trap at the lower end of these. The manhole may be covered by an iron locking grating, or, where this is considered

undesirable, by an iron locking door, air-inlets being provided by channels carried into the manhole from suitable positions. One great advantage of this plan, besides the facility it affords for getting at the drain and the trap, is, that if at any time air escapes from the air-inlets, the air that comes out is the last fresh air that has entered the manhole, and so practically these inlets never become a nuisance. As it may be desirable to get at the drain beyond the U-trap, although this is not very likely, it is better to fix a Y junetion beyond the trap, and bring pipes from this up into the side of the manhole, closing the end with a plug, which can be cut out if necessary. The floor of such a manhole, with sloping sides and two side inlets, is now made in one piece of stoneware by Messrs. Doulton, and sold under the name of the "Kenon Floor," and the U-trap with an arm brought from the farther end of the trap and ending just over the inlet to it, this arm serving for access to the drain beyond the trap, is also made by them, and sold under the name of the "Kenon Syphon." A fault that is frequently committed in the fixing of U-traps and drains is that sufficient fall is not given to the drain immediately before the trap.

Sometimes two syphons, or U-traps, are placed on the house-drain, one after another, with a ventilating-opening between them; the idea being that if the water in the syphon farthest from the house is forced by the sewer-air, this escapes by the ventilating-opening and does not get into the house-drain; but this presupposes that the main sewer, or cesspool, is very insuffieiently ventilated, and in practice it is found that two traps are, to say the least, quite unnecessary. It would be an excellent thing if we could do without water-traps (at any rate on the housc-drain) altogether; and I certainly look upon it as a mistake to have more than one. Drains are very frequently laid without inspection-pipes—a great blundcr, as if the drain has to be examined at any point the pipes have to be broken, and there is considerable difficulty in fixing new ones; indeed, the usual plan is to patch up the opening that has been made. Inspection-pipes should be placed at the heads of branches and in various places throughout the course of the house-drain, especially at or near bends, and the stones in the pavement over the positions of the inspection-pipes should be marked. Another mistake that is very commonly made is to have the drains covered in before a plan of them has been prepared. This plan should not only indicate the course of the drain, but the positions of all junctions, connections, inspection-pipes, and all other particulars which may be useful at any future time. Sometimes the drains of two or more houses are connected together before entering the main sewer, so that there is only one junction with the main sewer for these houses. This is known as the system of Combined Drainage. It is not to be reeommended; as, through the fault of one householder, the drainage of several houses may be stopped, and as there is only one entrance to the main sewer, anything impeding the flow of sewage in this, affects all the houses connected with it. But oecasionally the drainage of one or more houses passes, wholly or partially, through the drain underneath another house into the main sewer, so that the drain under the house in question becomes in effeet a public sewer for other houses. This ought never to be allowed, as not only does it considerably increase the possibility of this drain becoming blocked, but it increases considerably the possibility of disease being communicated from the neighbouring houses to the one under whieh runs the common drain; for while under the system of combined drainage—properly so ealled, as already deseribed—each householder can have a

proper disconnecting-arrangement to separate the drain of his house from those of other houses, when the drains of several houses are connected with the drain passing underneath a particular house, although the owners of these houses can isolate themselves by a disconnecting-arrangement, the owner of the house in question cannot do anything of the kind; all he can do is to isolate the common drain running underneath his house from the main sewer. This is so serious a defect in the arrangements of a house, that it has been recently decided by the Court of Chancery that any lease of a house possessing this defect is void, unless it is specially mentioned in it that the *sewage* of other houses is to be permitted to pass through the drain; and that it is not sufficient to provide in the lease that *water* from other houses is to be permitted to pass through.

At the time of writing a house situated in a square in the western part of the metropolis is in very much this difficulty. The drain from a neighbouring house passes into the drain of the house mentioned, which therefore has to do duty for two houses. Owing apparently to some fault in the sewer, the terminal end of the drain is choked, and the owner of the house referred to is obliged to submit not only to the risks attendant upon the sewage of his own house forcing its way up through the traps, but also that of his neighbour's, a condition to which he must submit until the local authority can be induced to reconstruct the same.

YARD-DRAINAGE.

It is clear that there must be openings into the drain at various places for the entrance of surface-water from areas, yards, &c. Not infrequently these are found untrapped: that is to say, there are direct communications from the surface of the yard through a grating or perforated stone into the drain below (Fig. 341). There are two disadvantages in this plan. The first is that fine gravel, dust, &c., from the yards is washed down by the rain, or swept down directly into the drains, and is liable to form deposits in them; the second is that these openings become ventilating-shafts for the drains, and are in many instances, at any rate, liable to cause a nuisance; nevertheless, with badly-constructed and imperfect systems of drainage-arrangements, they have very frequently proved a safeguard, as they allow an otherwise unventilated drain to be ventilated outside the house. More frequently, however, some kind of trap is placed underneath the grating, or other openings leading from the surface of the yard into the drain. The trap that is most commonly in use for this purpose is the worst of all traps. It is known as the "Bell-trap," and consists of an iron box, which can be let into a hole in the pavement over a pipe leading to the drain, and which has a small pipe standing up in it, and passing through the bottom of it. Underneath the perforated covering of the box is fixed an iron cap, or bell; the water, of course, stands in the box, when there is sufficient water in it, up to the level of the pipe leading into the drain. When

Fig. 341.—Untrapped opening into Drain in Area.

the cover is in its place, the rim of the bell dips a short distance into the water in the box, around the overflow-pipe, and so any air from the drain coming up the latter gets into the bell, but is prevented by the water from passing through the trap. This trap has very serious disadvantages. It always retains a quantity of mud or filth of some kind in the box, around the overflow-pipe. The small quantity of water is frequently reduced by evaporation, so that the bell no longer dips into it (Fig. 342) when the foul air escapes. On account of the small holes in the cover, and of the shape of the trap itself, water does not quickly run through it, especially as the holes are liable to be stopped up. So the cover gets removed, bell and all, and a free opening into the drain is produced, and as the cover is very often not replaced, the advantages of the trap are lost; this, too, is also the case when, as not infrequently happens, the bell gets broken. In short, the two fatal defects of this trap are, that it collects foul matters, and that the trap itself is removed when the cover is taken off.

Fig. 342.—Bell-trap, with water reduced by evaporation, so that the "Bell" no longer dips into it.

If this is a bad trap in areas and yards, it is still worse in any position inside the house; yet it is not at all infrequent to find several of these traps in the basement of a large house, some of them disused for years, and ventilating the drain into the house. When it was formerly the practice to swill down sculleries and various other parts of the basement with water, it was necessary to have some entrance, or entrances, into the drain, for this water to run away. These were usually made directly into the drain, and "protected" (?) with bell-traps. The state of things was bad enough then, but it has been rendered worse by the practice of washing and scraping basement floors instead of swilling them down, so that these bell-traps become disused, often with the worst results. It is not at all uncommon to find one in the floor of a larder or dairy; still more common to find one in the floor under the scullery sink; and frequently to find one in the kitchen, under the hot-water tap, close to the fire, where it will be often found quite dry, from the fact that the tap does not leak, and that the heat of the fire soon evaporates the small quantity of water that is ever left in the trap.

In a case that recently came under my notice, an outbreak of inflammation of the lungs—a disease frequently produced by foul air—was caused in a school, although the sanitary arrangements of the house had recently been "put in order," by the foul air that came in through a dry bell-trap under a disused sink in the basement. It was thought, as is generally the case, that as the sink was never used there was no danger in it; but the parts of a house that are never used are generally, from a sanitary point of view, those from which danger is most to be apprehended.

The next form of trap most frequently used in such situations is the "Lip-trap" (Fig. 343). It consists of an iron box, somewhat similar to that of the bell-trap, with the outlet at the side instead of at the bottom—the outlet being guarded by a plate of iron, that passes downwards from the top of the trap and dips in the water, which of course remains in the box up to the level of the outlet. This plate of iron gives

the trap its name. On the top of the box there is a perforated iron grating covering, to allow the water to pass into the trap, and prevent substances from getting in to stop it up. This is not so bad as the bell-trap, because the cover may be taken off or broken without the trap itself being destroyed; but not being a self-cleansing trap, it becomes a receptacle for earth, dust, &c., and also, as it holds very little water, this is liable to be dried up by evaporation. It is therefore a bad form of trap, whether for use inside or outside of a house. Very frequently with both these traps—the bell-trap and the lip-trap—the iron box is not fixed with sufficient tightness into the pavement, or the cement around it has got broken away, and then, if, as is very frequently the case, they are merely placed loosely over a hole leading into the drain, the whole contrivance is worse than useless.

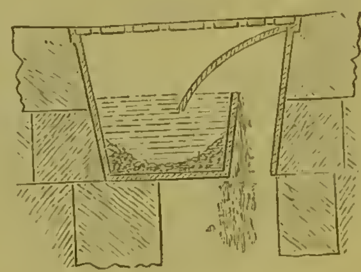

Fig. 343.—"Lip-trap."

Just as U-shaped bends and so called "Syphon-traps" are now made to fix in the drains themselves, so bent pipes which would hold water were devised for connecting the necessary gratings to carry off surface-water with the drains. The first of these is known as the "P-trap," and consists simply of a U-shaped pipe, with one limb of the U turned round horizontally, so that it can be connected with the drain. The bent part of the U holds the water, which forms the seal of the water-trap, and the vertical limb receives the water from the surface, through a grating fixed in the pavement. The S-trap is very similar to this, except that the limb which is joined to the drain, instead of being horizontal, is turned downwards, so that it is parallel to the vertical piece through which the water enters: it is, in fact, like the letter S placed sideways—thus ∽. As these traps, however, require a brickwork construction, or gully, built up to the level of the pavement, they are not all that could be desired, although far superior to other traps mentioned before; and now gullies, both with S and P traps attached, are made all in one piece of stoneware; they are self-cleansing, afford a large inlet to the drain—in fact, as large as the drain itself—and any sediment that may settle in them is easily removed by the hand. They are also made with inlet-openings above the level of the water in them, so that waste-pipes of various kinds, as mentioned in the preceding section, can be taken into them above the water.

Deep gullies are also made in stoneware, with a kind of pit below the level of the outlet, the object being to collect sand, &c., and so prevent it from getting into the drain; and sometimes they are provided with an iron bucket, that can be lifted out when it is full of sand. Stoneware gullies are also made with the upper part containing the inlet-opening in a separate piece, so that it can be fixed to the gully with the opening in any direction which may be most convenient; these are called gullies with reversible inlets.

In connection with the surface-drainage of yards and areas, it will be convenient to consider the *rain-water gutters and pipes*. Roof gutters are not infrequently made to run through the house from one side to the other, especially from the front to the back, in order to avoid having rain-water pipes down the front of the house. This is a very undesirable plan, as such gutters cannot be made air-tight, nor, as a rule, is there any attempt to make them so; and as soot and leaves collect in them,

the air that comes into the house through them is not only damp, but foul. They are, moreover, frequently left uncleansed for years, and a deposit a couple of inches deep is not infrequently found in them. Frequently they are passed through bed-rooms; and I have known several cases of illness, especially of sore throat, distinctly traceable to sleeping in rooms containing rain-water gutters. The gutters, therefore, should always be on the outside of the house where possible, and where it is impossible to place them outside the house, at any rate they should not pass through the sleeping-rooms. A lead pipe may sometimes be laid in the gutter from end to end, inspection-openings provided with brass caps and screws being fixed at intervals on it.

Fig. 344.—Open Rain-water Gutter under Bed-room Floor.

Rain-water pipes themselves, or "Down Pipes," as they are frequently called, are often carried through the inside of the house, and are, as a rule, made of cast-iron, with joints more or less imperfectly sealed. Generally some kind of trap is placed at the bottom of them, to prevent air from the drain ascending them, but frequently this is not done, even when they are inside the house; and it is not at all an uncommon thing to find a rain-water pipe, that might with perfect ease have been placed outside the house, carried down just inside the front wall, through every floor, including the best bed-room, the drawing-room, and the library, into the drain below. In such houses cases of illness of various kinds continually arise, and the cause is often not discovered for years; frequently a variety of other sanitary arrangements being put right, while this very serious one is overlooked. Whether the pipe is trapped or not at the bottom makes very little difference; as, if untrapped, air from the drain gets directly into it, while if trapped, it passes continually through the water in the trap, so that the air in the pipe is always full of this foul air, which is drawn through defective joints into the rooms, even when it is not actually being displaced by water coming down the pipe. Indeed, if the pipe is untrapped at the bottom, and there is an air-inlet into the drain, there is less chance of accumulation of foul air in it than if it were trapped. But even when the pipe is outside the house through its whole length, but is connected with the drain below, foul air frequently gets into the house from it, as the head is under the eaves of the roof, and frequently in close proximity to the top of a window; or the pipe begins in a gutter behind a parapet on to which the attic windows look, in either of which cases the air from the drain may be blown in at the windows; or if the pipe is trapped at the bottom, the foul air is displaced whenever there is a shower of rain, and may find its escape from the pipe, and enter the house in the same way. I have known a large number of cases of diphtheria and ulcerated sore throat, and I have reason to believe some of typhoid fever too, which have been apparently produced by this cause.

But rain-water pipes are occasionally placed in worse positions than these. They not infrequently pass through a water-closet in the basement or through the dust-bin, in which case the foul air from the closet or dust-bin may find its way through a leaky joint into the pipe, and out again into a room farther up, or into a balcony or conservatory, connected by a branch pipe with the one in question.

Very serious nuisances are sometimes produced in this way. Again, it is not at all infrequent to connect a water-closet with the rain-water pipe, and even with a rain-water pipe the head of which is not at the top of the house, but some distance down, in immediate proximity to a bed-room window. Of course this is most objectionable. Rain-water pipes, too, are not infrequently deliberately connected with the drain, and left untrapped at the bottom, with the intention that they should act as ventilators for the drain; but for the reasons already mentioned this is not a desirable plan, unless they are in positions where the air that escapes from them cannot enter any window, which is *not* frequently the case. It is even not at all infrequent, as I have already mentioned, to find the open head of a rain-water pipe inside the house, the foot of it being connected with the drain, and the rain-water brought into it by gutters from the roof. Sometimes, too, an open rain-water gutter inside a house is connected with the main soil-pipe, a trap of some kind being placed on it just before the junction, or even without this precaution (Fig. 345).

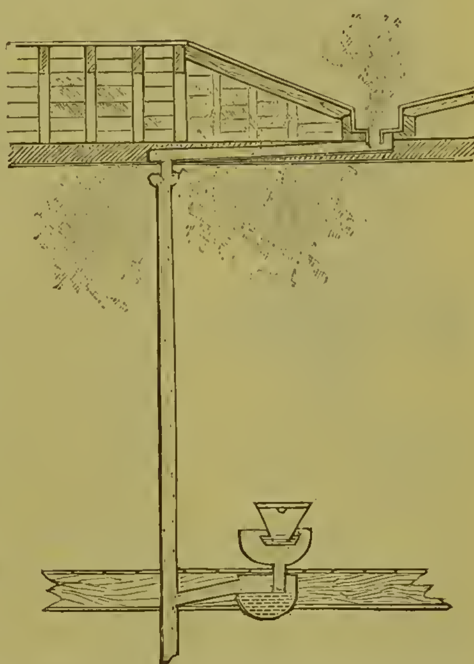

Fig. 345.—Soil-pipe with Open Head inside House, and Rain-water Gutter discharging into it.

Rain-water pipes, then, should be outside the house, and should not be connected in any way with the drain at the foot, but should discharge over the surface-areas, or if taken below the pavement, should be connected with the side inlets of the surface-gullies. Both rain-water pipes and gutters are sometimes made of zinc, but this is too perishable a material, and either lead or galvanised iron should be used. Ordinary cast-iron requires to be frequently painted, in order to prevent rust. Sometimes, however, the rain-water has to be collected in tanks, so that the rain-water drains do not enter the soil-drains at all; in this case the rain-water pipes are usually carried straight into four-inch drains, which are taken the nearest way to the tank—only the water from the roof being collected in these, the surface-water from the yards, &c., being discharged through gullies into the soil-drain. In this case it is necessary that the rain-water tank should be freely ventilated, if possible near the level of the ground, and should be cleaned out from time to time, as a sediment is apt to accumulate in it. If the ventilation is inefficient, foul air will collect in the tank, and passing up the rain-water pipes, may enter the house by some of the windows. In order to prevent leaves from collecting in the tank, it is also desirable to have wire gauze or perforated lead caps over the heads of the rain-water pipes, and at the entrances from the gutters.

SOIL-PIPES.

The pipes with which the water-closets are connected are often made of objectionable materials; occasionally, but rarely, they are made of zinc—a material which is

very readily corroded by foul air, and the use of which, indeed, for such a purpose is not defensible on any grounds whatever. They are more frequently, however, made either of iron, lead, or stoneware. The disadvantage of iron pipes for this purpose is that the joints are not always made securely; and the same may be said of stoneware pipes, with the addition that as stoneware pipes are as a rule only made two feet long, the joints are much more frequent than with iron pipes. When lead is used it is frequently too thin—say 4 or 5 lb. to the foot instead of 7 or 8—this being done, of course, to save expense. Seamed lead pipes are also frequently used, and by some deliberately chosen; they are made by cutting a long oblong piece of sheet lead, rolling it round into the form of a pipe, and soldering a joint the whole length of the pipe, whence they are named seamed pipes; but I have frequently found that these pipes have given way at the seam, and there are in the Parkes Museum several specimens of such pipes eaten into holes by foul air at the seam; so that the drawn lead pipe, which only requires to be jointed at the ends (the joints afterwards forming practically part of the pipe—and, indeed, the strongest part—and not being merely packed like the joints of an iron pipe), is much to be preferred. Nevertheless, what are called "slip joints" are sometimes used on lead soil-pipes: that is to say, the ends of the pipes are not soldered together, but merely slipped one into the other, as is frequently, and, indeed, usually, done with lead rain-water pipes. This again, is most objectionable in soil-pipes, as it provides a series of insecure joints. Soil-pipes are, of course, frequently placed throughout their whole length inside houses, although they ought, wherever it is possible, to be fixed entirely outside, in which case galvanised iron pipes may be used for them instead of lead. They are frequently not merely inside houses, but, like rain-water pipes, pass through rooms, and not infrequently through the larder in the basement. They are sometimes carried nearly horizontally from one part of the house to another (Fig. 347), often under a bed-room floor, and are buried in walls, so that they cannot be got at and examined. Sometimes they are not connected with the drain at the foot at all, but carried through the floor of the basement, and left to discharge their contents at a distance of five or six inches from the mouth of the "junction," or from a hole cut in one of the pipes (Fig. 346). Thus a small cesspit is formed under the basement of the house. Sometimes they are trapped at the foot—and, indeed, this used generally to be the practice—but

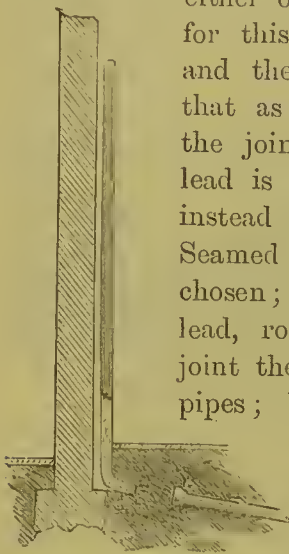

Fig. 346.—Soil-pipe not connected with the Drain at foot.

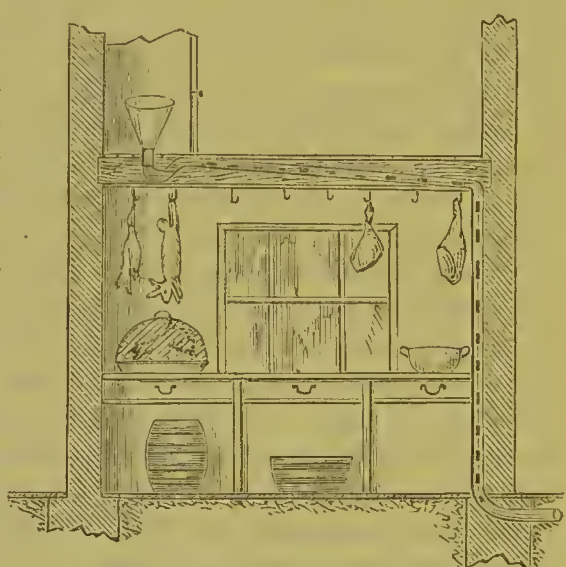

Fig. 347.—Holes made by Foul Air in an unventilated seamed lead Soil-pipe passing through Larder.

there is no advantage in it, and, as a general rule, they are better directly connected with the drain, provided that the latter is ventilated and properly disconnected before its junction with the main sewer or cesspool.

Soil-pipes are not infrequently fixed closed up at the top: that is to say, the pipe begins at the highest water-closet, and is carried down to the drain, receiving perhaps the branch pipes from one or two of the closets on its way. In this case it is, of course, always full of foul air, which, though the pipe is made of lead, soon eats its way through it in numbers of places, and afterwards finds its way continually into the house. A large number of cases of illness have been traced to the existence of these perforated soil-pipes. Such perforations are especially apt to occur at the upper part of the pipe, and above the water-line in those pipes which have been fixed nearly horizontally. A remarkable specimen of this is to be seen at the Parkes Museum, being a part of a soil-pipe that was found underneath a bed-room floor. It is perforated with holes made by the foul air from end to end. But when the soil-pipe is not entirely closed at the top, the means of exit provided for the foul air is often very inadequate. Thus, 4-inch pipes being almost universally used for soil-pipes, a 1-inch pipe is not at all infrequently fixed at the top to act as ventilator, and carried above the roof. This is, of course, better than nothing, and prevents an accumulation of foul air under pressure; but nothing short of a ventilator the same size as the soil-pipe can be considered to be sufficient; in fact, the pipe itself should be carried on up above the roof, and left to end wide open. Sometimes this ventilating-pipe is made to end too near the windows (Fig. 348), in which case the air from it is liable to be blown into them. I have known a 2-inch pipe carried from the soil-pipe of a closet on the first floor of a house, and made to end close to the landing window of the nursery floor.

Fig. 348.—Small Ventilating-pipe taken from middle of Soil-pipe and ending under a Window.

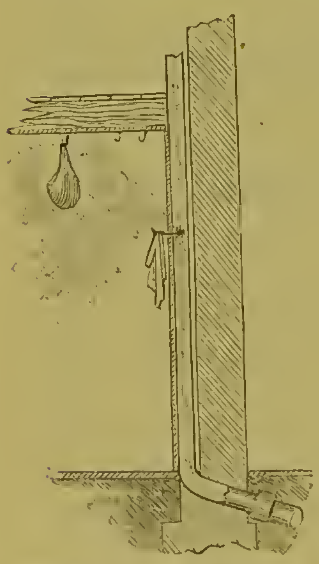

Fig. 349.—Nail driven into Soil-pipe in Larder Wall.

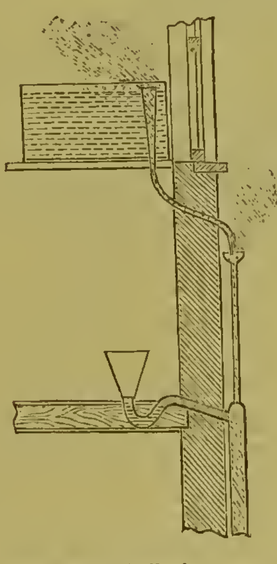

Fig. 350.—Soil-pipe ventilated under Window.

To show the importance of fixing soil-pipes where they can be seen and got at, I may mention a case in which there was a bad smell in a larder, the source of which was not found out for a long time, until it was observed that the soil-pipe from one of the closets, the course of which had not been traced, must be buried in the wall of the larder. Then, on taking hold of an old nail which had been driven into the wall, and on which some larder-cloths were hanging, it came out with the greatest ease, and it was

found that it had been driven into the soil-pipe. This soil-pipe, too, was unventilated (Fig. 349).

Fig. 350 shows a curious instance in which the small ventilator of the soil-pipe had an open conical head on it under a window, and the waste-pipe of the cistern discharged into this head.

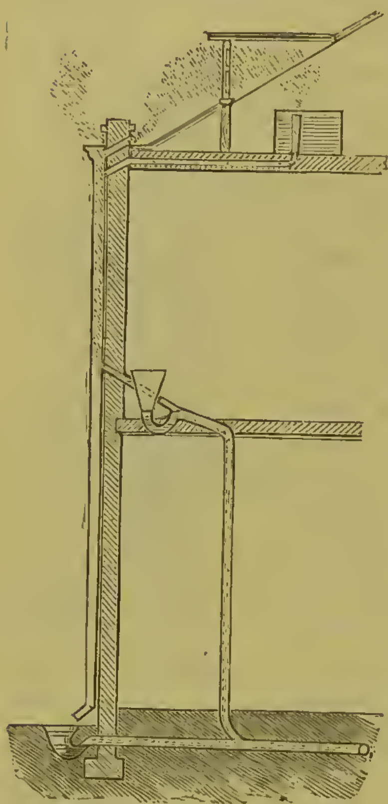

Fig. 351.—Rain-water Pipe properly disconnected at foot but with Ventilator of Soil-pipe and also Waste-pipe of Cistern connected with it.

The ventilator of the soil-pipe is sometimes connected with a rain-water pipe, the head of which is under an attic window, and I have seen the waste-pipe of a cistern supplying drinking-water connected with the same rain-water pipe (Fig. 351).

Sometimes it is considered desirable to disconnect the soil-pipe from the drain at its foot, by means of some trap with the air-inlet, and a variety of such traps are in the market. In this case, however, the drain has to be ventilated by separate pipes, and by this plan the number of traps and also of pipes about a house is increased, without, I believe, any corresponding advantage. The more usual plan now is to connect the soil-pipes directly with the drains by means of stoneware bends, so that the soil-pipes themselves may ventilate the drains, and then to disconnect the drains from the main sewer or cesspool by means of a trap, with an air-inlet or a ventilating manhole, as has been already described under "Drainage."

Such are the common defects, as met with in practice, of drains and soil-pipes; leading to the retention and accumulation of offensive matter within them, and to the escape of emanations from them into the dwelling-house—a condition only too frequently discovered when some serious accident to health, or even life, has led to a systematic search for the cause.

CHAPTER LXXII.

DEFECTS IN INTERIOR SANITARY FITTINGS.

Water-closets—Defects of the Pan Closet and of D-traps—Valve Closets—Plug, Wash-out, and Hopper Closets—Bad Joints—Water-service—Sinks—Baths.

WATER-CLOSETS are very frequently placed in most undesirable positions—sometimes in the centre part of the house, without any external ventilation at all, in cramped positions, under staircases where proper ventilation is impossible; not infrequently in dressing-rooms directly connecting with bed-rooms; sometimes built out as little additions to bed-rooms, with nothing but a small wooden partition to separate them from the rest of the room; not at all infrequently, too, they are fixed in cupboards in bed-rooms with absolutely no ventilation at all, and are, in fact, part of the furniture of the room. Contrivances of this kind are found most frequently in houses where there is plenty of space at hand, simply because they are thought to be convenient. The water-closets in the basement are too frequently placed in most improper situations—at the end of dark passages without any ventilation, or opening directly out of the pantry, the scullery, or, still worse, the larder. The water-closets in the basement should always—where it is not absolutely impossible—be out of doors; so should the ground-floor closet or closets where this is practicable; and the upstairs closets should be separated by ventilated lobbies from the rest of the house. If the positions in which water-closets are placed are often bad, many of the forms of apparatus used are often at their best very unsanitary appliances.

PAN CLOSETS.

The worst form of all is the one which is most commonly used, especially for upstairs closets. It is known as the "Pan Closet" (see page 140), and its construction is as follows:—Below the conical china basin is placed the "pan," a movable vessel, something like a bowl, made of tinned copper, and capable of being swung to and fro in a large box, generally made of iron, called the "container"—the lower part of the conical basin being fixed in a hole in the top of this container. At the bottom of the container is a 3-inch outlet-pipe, which is usually connected with a trap of some kind or other, placed beneath the floor—the outlet-pipe from this trap being connected with the soil-pipe. From this construction it will be seen that when the pan is in its place beneath the basin, and full of water, the lower end of the basin dips into the water, and so forms a water-seal between the container and the room in which the closet is, and when, by means of a pull-up apparatus or other such device, the pan is removed from below the basin, its contents are thrown into the container,

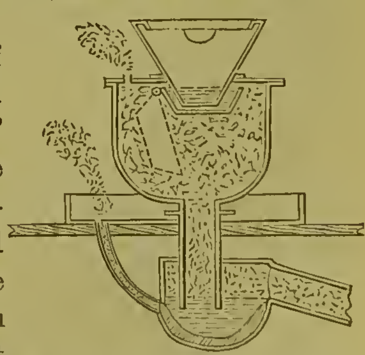

Fig. 352.—Pan Closet with Foul Air escaping from Container by Ventilating-opening. Waste of Safe into D-trap.

and from it into the trap below. During this process a certain amount of splashing of the inside of the container takes place, and so this becomes after a time lined with a foul deposit. Thus the air in the container is kept continually foul, and every time that the handle of the closet is worked some of this foul air is displaced by the pan and forced into the room. Several devices have been resorted to in order to obviate this evil. The first, and most common, is that of ventilating the container, which is often attempted to be done, but is, of course, done very imperfectly indeed, by boring a hole in the top of it, connecting a small pipe to this, and carrying the same through the wall of the house into the open air. This, of course, prevents any accumulation of foul air under pressure in it, but does not cause a current of air, and with this object occasionally two such pipes are fixed. I have seen several instances where pan closets—the containers of which had holes bored in them for ventilating-pipes—had been fixed in houses without any ventilating-pipes being attached to these containers, and in one instance this was done in all the water-closets in the house, one of them opening directly out of the best bed-room, the result being an outbreak of diarrhœa in the house. In such cases, when the handle of the closet is pulled up the foul air is forced out of the container, through the small hole in it, into the space under the closet-seat, with a rush that will blow out a candle (Fig. 352). It has been proposed to flush the inside of the container by means of a series of jets of water supplied by a pipe connected with the supply-pipe to the closets, so that each time that the handle is raised the inside of the container is washed. Some pan closets are also made with stoneware containers, presenting smooth surfaces inside, and so less liable to become coated with the foul matters that are splashed upon them. But these are only very partial remedies for the evils of the container. The trap generally, indeed almost universally, fixed beneath the container of the pan closet is that known as the D-trap; so called from its being shaped like the letter D (see Figs. 73 and 352). The inlet-pipe which is connected to the container of the closet passes down into the trap, and dips into the water contained in it, which of course stands at the level of the outlet-pipe, this being placed at the upper part of one end of the trap. It will be seen from this description, and from the diagram, that this is a trap which can never be properly flushed by the water that passes through it, and thus foul matters collect in it, coat the sides of it, and, decomposing, keep the water in it and the air in the container above it always foul. This is, therefore, a very bad form of trap, and should never be used in closets or anywhere else; indeed, its use is now condemned, and very properly so, by the model by-laws of the Local Government Board.

D-traps, even when made of stout lead, are very frequently eaten through by the foul air in them, especially if they are not ventilated, and the foul air then escapes into the house. Sometimes D-traps are made of very thin lead, and, not only so, in one instance I found a D-trap under a water-closet made of zinc, with a zinc soil-pipe leading from it into an iron pipe which was connected by a 4-inch stoneware drain with an unventilated cesspool. The safe-tray was made of zinc, with a zinc waste-pipe discharging into the trap; the waste-pipe of the housemaid's sink was also made of zinc, and discharged into the zinc D-trap of the closet; and the lead waste-pipe of the cistern over, which supplied both closet and sink, also discharged into the D-trap of the closet. The top of this trap was riddled with holes made by the foul air. The result of this state of things (which led to

its discovery) was an outbreak of sore throats for a second time in the house. The trap and the pipes connected with it are now in the Parkes Museum of Hygiene.

The pan closet, then, and the D-trap, whether separately or together, are nuisances, being constructed on bad principles. They should never be fixed on any account, and should always be removed wherever they are found.

A lead tray, called the "safe-tray," is usually fixed under the water-closet apparatus, to catch any overflow or leakage; and its waste-pipe is frequently taken into the trap of the water-closet, and forms an additional channel for foul air to enter the house; it should be carried through an external wall, and have a brass flapper on its end to prevent draughts coming in through it.

VALVE CLOSETS.

The various forms of valve closet (see Fig. 74) are also very largely in use, and are all of them far superior to the pan closet just described. In them the basin is usually made bowl-shaped instead of conical, and the outlet at the lowest part of the basin is fitted with a water-tight valve, which can be moved to and fro in a small box, called the valve-box, or conductor, by means of an apparatus connected with the handle of the closet. From the valve-box, or conductor, an outlet-pipe passes into the trap below. As the valve fits water-tight to the bottom of the basin, an overflow-pipe is usually provided for the basin to carry away any excess of water that may be thrown into it, or may trickle through a leaky valve in the cistern or on the supply-pipe. This overflow-pipe generally has a small U-shaped bend on it, and is then connected with the side of the valve-box, or conductor—the result being that in many of these closets the water is drawn out of the bend in the pipe, or it is unsyphoned whenever the large body of water in the basin is, by the pulling up of the handles, and the removal of the valve from the bottom of the basin, allowed to fall through the valve-box into the trap below. Thus the trap on the overflow-pipe is left unsealed, and foul air may pass through the valve-box into the room of the closet.

The trap of this overflow-pipe may also get full of foul water, which deposits a sediment on the side of the trap, and so causes it to produce an unpleasant smell. This is especially the case when the overflow-pipe opens into the valve-box in front of the valve instead of behind it, as then foul matters are projected into it when the handle of the closet is pulled up.

The overflow-pipe, then, should discharge into the valve-box *behind* the closet-valve, so that the latter guards it when the handle of the closet is pulled up, and the contents of the basin are discharged through the valve-box.

There are several methods for preventing the overflow being untrapped. One is to attach a ventilating-pipe to the valve-box, and carry it out through the wall into the open air; another to attach a small branch pipe to the pipe which supplies the basin, and which is called the service-pipe, and to connect the branch pipe with the overflow just above its bend, so that the latter is supplied with water every time that the handle is pulled up, while the basin is being refilled; and another plan is to disconnect the overflow from the valve-box altogether, and either carry it out separately into the open air, or make it discharge into the "safe." Or the overflow-pipe may be dispensed with altogether, and the basin

allowed to overflow at the top into the safe-tray. Of course, by this plan any overflow is more certainly discovered than by any other; but the apparatus under the seat is liable to be rusted by the flow of water, and especially of foul water, over it. Where this plan is adopted the basin should have a lip to direct the overflowing water into the safe-tray without allowing it to run down the apparatus.

SOLID PLUG CLOSETS.

There are various kinds of water-closets with solid plugs lifted by the handle directly by means of a straight rod. In these closets the outlet is necessarily at the side, and is not seen; it is liable to become foul by foul matters being caught by the plug in descending, and so a foul smell is sometimes observed in these closets, usually coming through the hole in which the rod of the handle moves, and this is especially the case where there is a trapped overflow connected with the trap or soil-pipe below the plug.

These closets and some others are occasionally fixed without any water-trap beyond that provided by the water-seal in the basin; but this is a plan not to be recommended, as an updraught from the soil-pipe may take place into the closet when the handle is pulled up, and may go on for a considerable time if, as is sometimes the case, the handle is fastened up. I believe that no precautions are sufficient to prevent this, and I have frequently noticed a foul smell from the soil-pipe in closets so constructed.

WASH-OUT CLOSETS.

There are several patterns of what are called "wash-out" closets now in the market (see Fig. 79, &c.), the object of which is to provide a simple and cheap closet without any valve, but still holding water in the basin. Most of these closets, however, require a considerable quantity of water to flush out the contents of the basin, and to keep the trap clear; and the depth of water in the basin is too shallow to be of much service, so that in practice it is found that, as a rule, they do not keep clean.

The outlet in these closets is necessarily at the back or side, and not at the bottom of the basin, which latter is, in my opinion, the proper place for the outlet of a closet-basin.

HOPPER CLOSETS.

We now come to hopper closets. The common hopper closet with a conical basin, stoneware syphon-trap, and inlet-arm for the water-service (see Fig. 263), has several serious defects besides the obvious one that the water does not stand up in the basin.

In the first place the shape of the basin is bad, and this has been obviated in the improved forms of hopper, by making the back of the basin more vertical than the front. The inlet-arm being at the side of the basin causes the water to whirl round and round the basin, a motion by which neither is the basin kept clean nor the trap swept out; and this is prevented in the newer forms by providing the basin with a flushing-rim from which the water falls straight down the sides of the basin all round, collecting in the trap and cleansing it out effectually (see Fig. 77).

THE JOINT WITH THE SOIL-PIPE.

Whatever kind of water-closet is adopted, a serious danger arises if the trap under it is badly jointed to the soil-pipe, as, in that case, drain-air passes directly into the house. For this reason the trap for an upstairs water-closet should be part of the soil-pipe, and for a basement water-closet part of the drain, and not, especially in an upstairs water-closet, part of the closet-apparatus; the joint which is most likely to give way should be between the water-closet apparatus and the trap, and not between the trap and the soil-pipe or drain. The trap for an upstairs water-closet should be one of the forms of lead syphon-trap, and for basement water-closets a stoneware syphon-trap.

Unventilated syphon-traps are more readily unsealed than D-traps are, so the arm of each water-closet requires a separate ventilating-pipe starting close to the trap and carried into a small pipe outside the house, ending wide open out of the way of the windows. The "V-dip" trap, and the smaller "Anti-D" trap have been devised to obviate this tendency of syphon-traps to be unsealed, especially where there are several water-closets one above another discharging into the same soil-pipe.

I have not considered it necessary to describe the great variety of water-closets now in the market in detail, but merely to point out the leading features, and especially the defects, of the classes of water-closets in most general use.

WATER-SERVICE TO WATER-CLOSETS.

When water-closets are supplied directly from cisterns also supplying drinking-water, the danger which arises is greater or less, according to the mode in which the water-closet is supplied. The danger is great if the closet is merely supplied by a pipe from the cistern direct to the basin of the closet, with a tap on it, as if this tap is left open the water will all run out of the cistern, and foul air from the basin of the water-closet may, and very likely will, be drawn into it from the open pipe (see Fig. 353). But this is a most reprehensible plan of supplying water-closets, and should be altered wherever it is found.

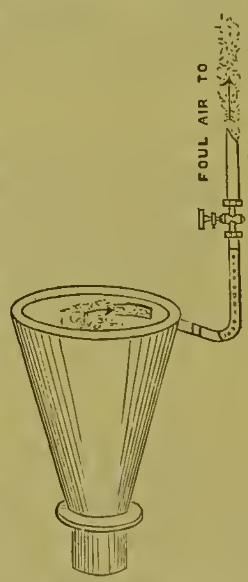

Fig. 353.—Water-supply direct from Cistern, and Water thereby contaminated.

Tho danger of this plan is still greater if the water-closet is supplied, as it ought not to be, direct from the rising main, as then, when the water is turned off, if the tap in the service-pipe to the closet has been left open, foul air and even solid and liquid filth may be drawn from the basin of the closet into the water-pipes, to be washed into the cisterns the next time that the water is turned on. Epidemics of typhoid fever have been traced to this method of pollution of the drinking-water.

Danger also arises if the water-closet is supplied by means of a spindle valve in the closet, which is lifted by means of crank and wires when the handle of the closet is pulled up, as in this case a little filthy water is squirted from the ventilating-pipe of the valve-box into the water of the cistern each time that the handle of the closet is pulled up.

There is another objection to this plan of supplying the closet with water, even if the cistern does not supply drinking-water; and that is, the time that the water takes to flow from the cistern into the basin of the closet, which necessitates the holding up of the handle for a longer or shorter time, according to the length of the pipe that the water has to descend.

When the closet is supplied by means of a valve fixed under the seat of the closet so that the service-pipe from the cistern to the valve is always full of water, the chance of contamination of the water in the cistern is almost nothing; but it is still conceivable that the handle of the closet might be fixed up so that the valve remained open, and then when all the water ran out of the cistern air from the basin of the closet might pass up into the cistern. Even with this precaution, therefore, (which is generally considered to amount to perfect safety) it is not advisable to supply water-closets from a cistern also supplying a draw-off tap, and the plea that the drinking-water is drawn from some other tap must not be allowed. The proper plan is to consider that every tap from which water can be drawn is a drinking-water tap, for it sometimes will be so.

When water-closets are found to be connected with the drinking-water cisterns, they may be frequently disconnected by giving the actual supply through small subsidiary cisterns, or of water-waste-preventing cisterns supplied by the pipe which comes from the drinking-water cistern. But unless the closets are supplied with a regulator-valve under the seat the common forms of these waste-preventers do not give a sufficient flush, and should be discarded for the new syphon-action water-waste-preventers, of which there are several kinds in the market, which discharge the whole of their contents when the handle of the closet is pulled.

The service-pipes of water-closets are often $\frac{3}{4}$ inch in diameter, which is not sufficient to produce a proper flush so as to keep the basin clean; they should always be larger than this, and the size must be regulated by the height from which the water comes.

URINALS.

Like water-closets, urinals are often placed in most objectionable situations, and are improperly flushed with water. They should not be allowed, and are not necessary *inside* private houses at all, although it is necessary in large houses to have them outside. They are always liable to become a nuisance, but when untrapped, as is sometimes the case, they cause a very serious one.

SLOP-SINKS.

Slop-sinks also invariably cause a nuisance in the house when they are not flushed with a large quantity of water, and in houses of moderate size it is better not to have slop-sinks at all, but to have the slops thrown down the water-closet, the seat of the closet being made to lift like the lid so that the slops will not be thrown over it. This arrangement offers the additional advantage that the closet-apparatus can be examined at any time, and the safe-tray cleaned out if necessary. It is very important that this should be done from time to time, as, if foul water remains in the safe-tray, it produces an unpleasant smell in the closet, and although all the water may run out of the safe by the waste-pipe if the latter is at the lowest

part of the safe (which is unfortunately not always the case), the tray is left damp with the foul water, and a sediment is left on it which soon decomposes and smells badly.

Another plan for obviating this difficulty is to have a water-closet and slop-sink combined, and a basin is now made by Messrs. Dent and Hellyer with this object. In this there is a china tray around the basin of the closet and immediately under the seat, so that when slops are thrown into it they cannot run over into the safe, being caught by the china tray, which slopes gradually into the basin of the closet.

HOUSEMAIDS' SINKS AND PANTRY SINKS.

The waste-pipes of housemaids' sinks are very frequently found to be connected with the trap of the nearest water-closet, or they have a trap on them and are then connected with the soil-pipe, or they are taken straight down through the house into the drain.

The waste-pipes of pantry and other basement sinks are frequently connected with the drain or with an unventilated trap (Fig. 331).

All these methods are most objectionable; the wastes of sinks should on no account be directly connected with any part of the closet-apparatus or drain, but should be taken through the wall of the house, either into the open head of a pipe discharging over a gully below or into it above the water-line, or into a pipe which is carried up above the roof as ventilator. Although the waste-pipes of the sinks are thus disconnected from the drains, they still require to be trapped, or otherwise air will come into the house through them, especially when the windows are shut; and the waste-pipes of sinks, especially when of considerable length, as they sometimes must be, being more or less foul inside, are not proper conduits to act as inlet-ventilators for the house: the air that comes in through them cannot be sweet. But under these circumstances D-traps should not be used, as I have very frequently had to remove them from under sinks and lavatory basins on account of the nuisance caused by the accumulation of soapsuds and dirty water which they contain; cast-lead syphon-traps with cap and screw, of the same size as the waste-pipe, should be used.

Bell-traps, too, are often found upon sinks, the waste-pipes being generally in this case carried into the water-closet trap, or trapped again below the floor; but it is not at all infrequent to find, especially in the basement of the house, that the bell-trap in the sink is its only trap, and that as soon as it is removed foul air from the drain rushes into the house, often with sufficient force to blow out a candle.

Sometimes when this is discovered, the waste-pipe is disconnected from the drain or water-closet apparatus and carried outside, while the bell-trap is left in the sink. This should not be done; as the bell-trap, for the reasons already described, is a bad form of trap, and it should be replaced by a plain brass grating with syphon-trap fixed under the sink, or in some cases by a trap known as the "Antill" trap (Fig. 254).

SCULLERY SINK.

A special difficulty occurs in the case of the scullery sink, from the large amount of grease and sand that is discharged down it. Any kind of receptacle for this

grease and sand, if placed inside the house, may cause a serious nuisance; and, if placed outside the house, is very little better. For small houses, especially when the drain has a good fall, I believe nothing of the kind is necessary, the fat and sand collecting sufficiently in the gully into which the waste-pipe is discharged, which has to be cleaned out from time to time and, if it be thought desirable, a gully with a lifting bucket in it (such as "Dean's" trap, Fig. 256), may be used for the purpose of collecting the sand; but in large houses a receiver of some sort (Figs. 258, 259, 260) is, in the majority of instances, bound to be a necessary evil, as the amount of grease that is thrown down the scullery sink is so great that it clogs up the pipes in a very short time, and I have frequently seen pipes taken up completely choked up with a mixture of grease and sand. This is especially the case where the scullery sink is not, as it ought to be, against an external wall, so that the drain from the waste-pipe runs underground some little distance before it can be disconnected by means of a gully in the yard. In this case the grease gets congealed around the sides of the pipe, and very soon chokes it up.

BATHS.

The same must be said of the waste-pipes of baths, which require to be treated in the same manner; but with baths there is an additional warning: there is usually a safe-tray of lead or zinc underneath the bath to catch any leakage from the cocks, or from any defect in the bath. The waste-pipe of this safe-tray is also frequently taken into the closet-trap; it ought to be carried through the wall to end in the open air, with a brass flapper on its end to prevent draughts coming up it.

Sometimes the water is supplied to the bath for a certain distance through the waste-pipe, so that the clean water comes in at the same place that the dirty water goes out. This is a bad plan, as the clean water in coming into the bath brings back with it the dirtiest part of the water that was last used—*i.e.*, the part containing the sediment at the bottom of the bath.

The waste-pipes of baths are often too small, the result of which is that the bath empties very slowly, and that the flushing-power that the bath-water ought to exercise upon the drain is frittered away.

The waste-pipes of baths should be $1\frac{1}{2}$ or 2 in. pipes, and should discharge into open heads of pipes disconnected at the bottom in the same manner as described for the waste-pipes of sinks.

CHANNELS FOR FOUL AIR.

Foul air often travels about houses by most unexpected channels. Rat-runs have already been mentioned; but besides these it travels under floors, behind panelling and wainscoting, along ventilating-shafts, through defective flues, and even through the tubes in which bell-wires are carried, through which foul smells from the basement, and still more frequently the products of the combustion of gas-burners, often ascend into rooms upstairs.

DISPOSAL OF REFUSE BY DRY METHODS.

By The Editor.

CHAPTER LXXIII.

MODIFICATIONS OF THE OLD SYSTEM.

Necessity for Dry Methods—Midden System—Nottingham Midden—Hull Midden—Model Midden.

It is now necessary to turn our attention to the treatment of refuse matter in houses where there is no water-carriage system, and where we are therefore obliged to depend upon the removal by hand of the material caused by the presence of life. How this may best be done is a very wide subject, and one which has the most intimate relation with health.

With the water-carriage system we are able by a flush of water to remove at once from the precincts of the house matter which, from the beginning, is offensive, and which tends to become more so the longer it is retained, unless special precautions be taken, and in almost all towns, for, at any rate, some of the better-class houses, this system is provided, but the great bulk of a population is often obliged to adopt some other method for the disposal of its waste, and this method necessarily includes the retention of effete matter for a varying time upon the premises. So, again, in rural districts, the same provision must frequently be made, and, if considerations for health are to guide us, it becomes our duty to learn how, in our mode of dealing with it and in the choice of the form and kind of apparatus to be used, we may render it less prejudicial than it would otherwise be. To a very considerable extent, especially in large towns, the house-owner is not free to select that method which may best accord with his own wishes; he is dependent upon the requirements of the sanitary authority in whose district his house is situated; and inasmuch as he is unable himself to undertake the removal of the waste from his house, he is compelled to rely upon this authority for such service, and is obliged therefore to make such arrangements as they may deem to be requisite. Thus, if the removal take place at frequent intervals, he will require less room for storage than if these intervals be longer, and he must therefore adapt the planning of certain parts of his house to this end. So, again, the sanitary authorities themselves may not be altogether free agents in this matter; they must in some degree consider other questions than those which are related to health alone. In the choice between one method of conservancy and another they are naturally influenced by considerations of economy. They have in their turn to decide as to what shall be done with the refuse they have removed. In towns surrounded by a large agricultural area it may easily be disposed of for the purpose of manure, and the authorities may have no difficulty in selling or giving it to farmers, who will gladly use it upon their lands; in other towns, where farming operations are not carried on in the vicinity, this opportunity may not

exist, and the only alternative which may then present itself is the manufacture of the refuse into a material capable of being preserved or conveyed in a dry form to other parts of the country. But the need of adopting a course such as this in turn compels the authorities to make regulations which shall ensure the material they receive being fitted for the purpose to which it is their intention to devote it. According as it is treated in the dwelling, so it is rendered possible or impossible to dispose of it, so that some return shall be made for the cost of its removal from the house. It is beyond the scope of these pages to do more than mention incidentally the treatment which such refuse shall receive after its removal; but it would be well that this point should not be lost sight of, seeing how closely the house-owner is affected by such a consideration.

We must now enter more into detail and learn of what this waste consists. In all houses arrangements must be made for the disposal of slop-water, of animal and vegetable refuse from the kitchen, of ashes from the grates, and of the excreta of the inmates. In country districts slop-water need present no difficulty; it may be either emptied immediately into a tub and subsequently distributed over the ground, or treated in a manner described on page 665. But in all towns yard-drains should be provided, down which slop-water may be thrown.

The garbage, the ashes, and the excreta must be stored for a longer or shorter period; and it is to the arrangements which must be made under these varying conditions that our attention must be directed.

It will be well, in learning the rules which must guide us in adapting our house to the requirements of health, that we should make ourselves acquainted with some of the systems already adopted in different localities, and ascertain in what particulars they succeed or fail.

MIDDEN SYSTEM.

We may take as the type of all that is bad the midden, which was formerly found in all parts of the kingdom. In its worst form it consisted of nothing more than a mere hole in the ground, into which excreta, garbage, ashes, and slop-water were indiscriminately thrown. It requires but a slight effort of imagination to picture to ourselves the condition of such a receptacle, containing a large mass of decomposing animal and vegetable matter, with the filth constantly soaking into the ground, with every opportunity for rain-water to enter it, and frequently placed in close proximity either to the house, or to a neighbouring well which supplied the drinking-water for the household. A midden such as this is best calculated to cause the most serious injury to health. Writing in 1869, Dr. Buchanan thus speaks of the middens of Birmingham:—"At present it is common to find huge, wet, fœtid middens, uncovered, undrained, unemptied, some of them as deep and big as the foundations of an ordinary cottage. Few of them are covered, the inspector of nuisances thinking they are better left open. Many are under workshops, where work is done amid stench all the year round, and among swarms of flies in the summer."* Words could not better describe the effects produced by want of care in the construction of this pit; but of late years much has been done to lessen the objections to this method of refuse-disposal. Efforts have been made to prevent the soakage of the contents into the surrounding earth, to reduce the size of the pit,

* Twelfth Report of the Medical Officer of the Privy Council, 1869.

and to ensure the contents being in a dryer state than before. As an example of a midden which is a distinct improvement upon that we have described, the Nottingham

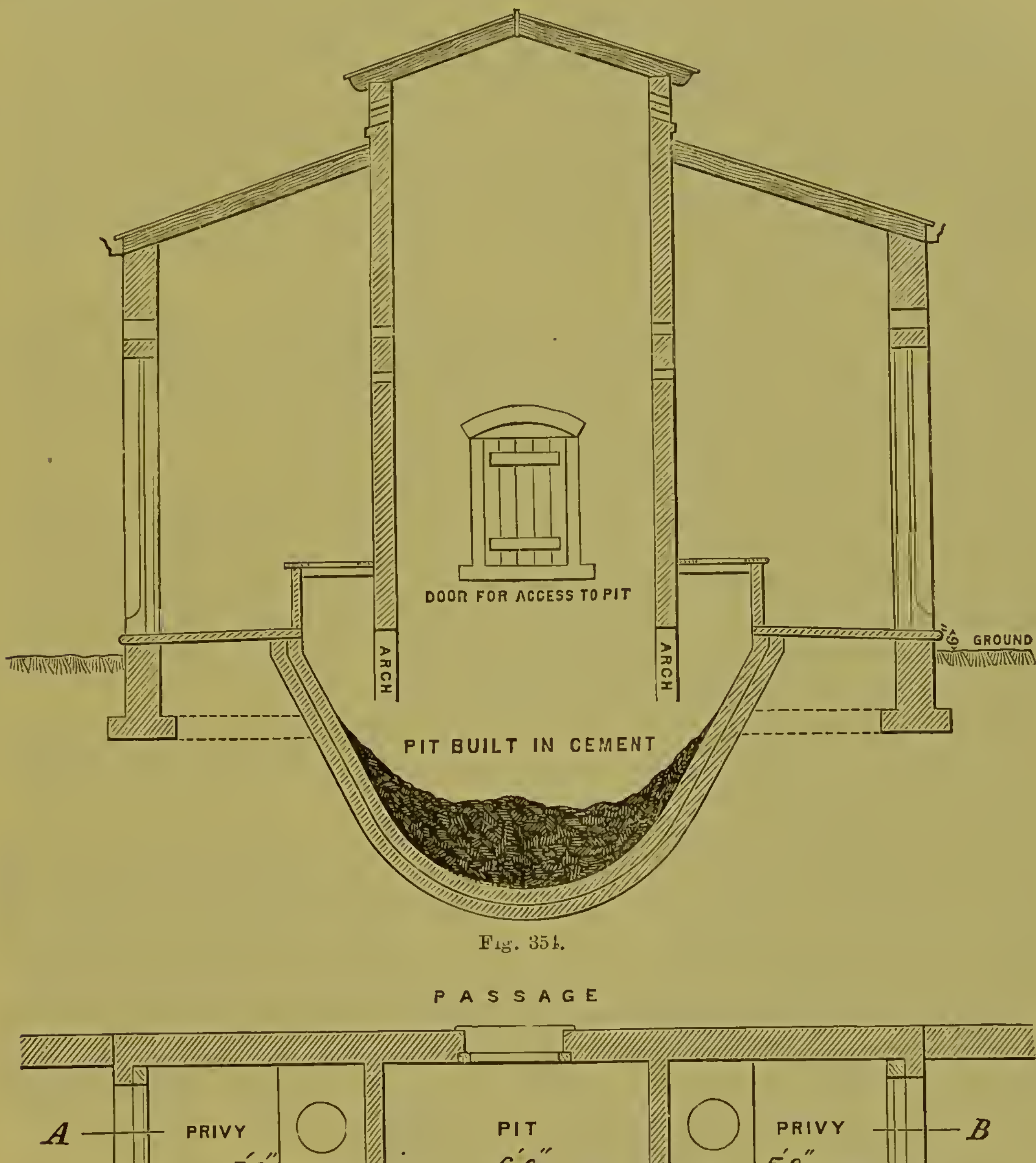

Fig. 354.

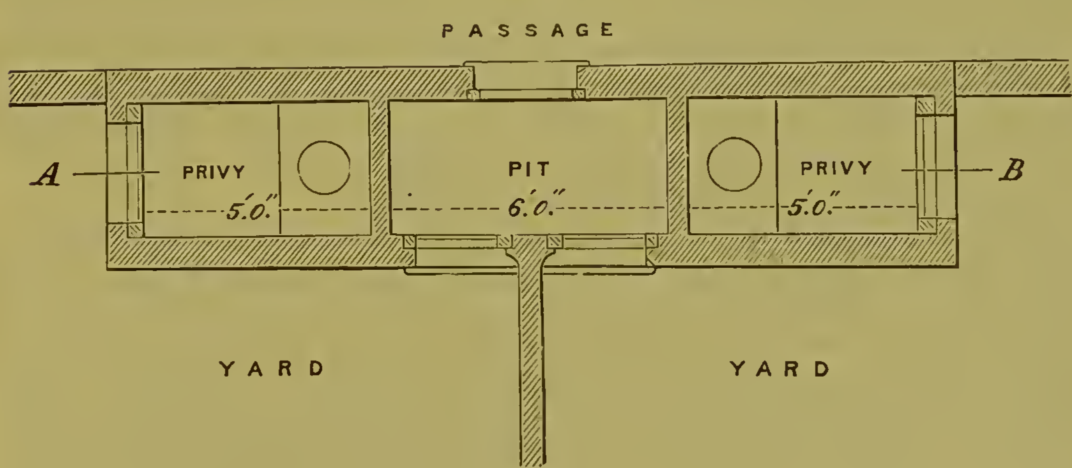

Fig. 355.

ash-pit may be taken as an example. The accompanying drawing (Figs. 354 and 355) which is supplied by the corporation of that town with a specification for builders, serves well to show the arrangement which ten years ago was considered

desirable. Here are two privies opening into the same ash-pit, while one small door on either side admits of the same pit receiving the ashes and garbage of the house. The pit, which is cleared once in every three months, is built in cement, is about 80 cubic feet in size, has a rounded bottom, and is sunk below the ground; a roof shuts out the rain from above, and opportunity for ventilation is afforded. That this midden did not answer every purpose will be seen from the following words taken from the report already referred to: "The closets were free from the intenser sort of nuisance which is usual when the midden is of large size; but, on opening the ash doors, considerable stench was found from those closets where the ashes, thrown in at the side or sides, had left the dejections near the centre of the midden to some extent exposed."

In Hull a further advance is made, for here the midden is almost entirely above the ground, and is limited to the mere space beneath the seat. It is built of bricks and cement, and has a paved bottom which slopes slightly from front to back. Ashes and garbage are thrown through the hole in the seat with a scoop, and the midden is readily emptied by the removal of the front.

From what we have said, it will be seen that if a midden is to be free from nuisance it must be very limited in size; and it will be recollected that this is tantamount to saying that it must be frequently emptied. It is, moreover, absolutely necessary that the pollution of the surrounding ground should be prevented. For this purpose no part of the middenstead should be allowed to be sunk, but its bottom should be above the level of the earth, and it should be built of such impervious material that soakage from it shall be impossible.

It should, as a further precaution, not be situated inside, or with its walls in contact with any dwelling-house, and opportunity should be given for the ventilation of the middenstead as well as the privy.

In some towns the ventilation of the middenstead is ensured by a shaft which is carried from below the seat to above the building, and a current of air is by this means kept almost constantly in circulation from the middenstead upwards; but wherever this is done, it is especially important that the shaft should not be carried near any part of the house where emanations from it could enter by the windows.

In the choice of its situation regard should be had to the need for it to be emptied, and under no circumstances should it be so placed that the contents would have to be carried through any inhabited house or building. Where possible, entrance to the midden for this purpose should be in the possession of the scavengers without need for them to enter the premises.

Not less necessary is it that the contents should be kept as dry as possible; the midden should therefore be provided with a roof for excluding the rain, for it is found that the tendency to decompose is very greatly increased by wetness. In some towns steps have been taken to drain into a sewer any excess of liquid the midden may contain; but experience has shown that this is a mischievous course, simply leading to blocking of the sewers with the ashes which are carried away by the liquid. This practice has been very properly condemned by Mr. Netten Radcliffe, who says that if this polluted liquid may be conveyed out of the middenstead into the sewers, "there could be no sufficient reason, either commercial or sanitary, for not sending all excrement together along sewers. Drainage is fallacious as the means of continuously draining off the liquid contents of a middenstead, and thus

promoting dryness of contents, as was observed everywhere in wetness of open middensteads presumed to be drained; and dryness can be secured in other and more effectual ways."

Another point also affecting the dryness of the contents is the shape of the midden-bottom. It is with this object that the rounded bottom of the Nottingham midden was designed, but experience in other towns has shown that where other precautions are taken a flat bottom answers every purpose.

The reference we have made to the Nottingham midden will serve to illustrate the value of ashes in preventing nuisance; wherever the excreta were well covered with this material there was infinitely less offensive smell than where the excreta were exposed. It is, then, upon the proper use of ashes that we have to depend for ensuring dryness and preventing smell.

There is some difference of opinion as to how ashes act; some believing that while the fine ash-dust is a deodorant, the larger cinders tend to promote decomposition, while others are satisfied that the cinders are useful in causing dryness of contents. However this may be, there is no doubt that ashes, either in fine dust or mixed with cinders, have a very considerable effect in preventing nuisance, and the question whether the latter should be permitted to enter the midden depends more particularly upon their value for fuel, and upon the subsequent treatment of contents.

The distribution of ashes may be accomplished in a variety of ways; two of these have already been mentioned in the descriptions given of the Nottingham and Hull middens, and a third, that in which the seat of the privy is hinged so that it can be raised up and thus admit the ashes, may be also referred to, a plan which is more frequently found in Manchester. Formerly in Salford the same result was attempted, by placing the midden immediately beneath the seat and floor of the closet, and raising the seat so that there was a step in front of it, thus leaving a space between the step and the floor through which the ashes were thrown in. This plan was, however, found to be objectionable, and has since been abandoned.

Latterly it has been thought well, for reasons relating to the subsequent conversion of the excreta into manure, to adopt a method by which the fine ashes only are passed through a cinder-sifter, and then scattered over the excreta. This sifter may consist merely of a sieve, which allows the fine ashes to fall on to the excreta, or a more complicated apparatus; the best form is that invented by Mr. Conyers Morrell, of the Sanitary Appliance Company, who has designed an ingenious arrangement by which the ashes are thrown through an opening in the side or rear wall of the privy on to a sloping board, which conducts them to the screener, or sieve. By the pressure upon the seat which occurs when the closet is in use, the screener receives a motion that separates the fine dust from the cinders, and passes the former into a measurer, whence it is discharged over the soil the moment the pressure is taken off the seat; at the same time the cinders pass over the screen and fall into a pail below, whence they can be removed for subsequent use as fuel. The accompanying illustration (Fig. 356) shows the form of this apparatus; it is now in use in many large towns, and is found to be exceedingly well adapted for the purpose of covering the soil with ashes.

The description of the midden we have given will, we trust, be sufficient indication of the difficulties which must be overcome if this method of refuse-disposal should be adopted, but under no circumstances can the midden fail to be more or less

objectionable; objections to it are, however, much lessened by attention to the details of its construction, and to its proper use.

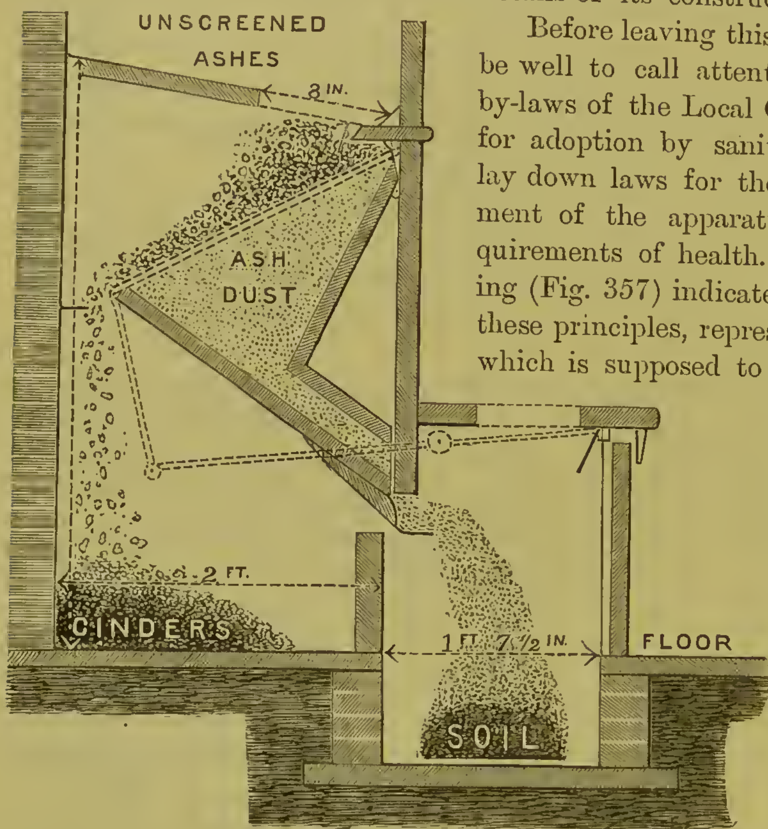

Fig. 356.—Morell's Cinder-sifter.

Before leaving this part of our subject it would be well to call attention to the admirable model by-laws of the Local Government Board, intended for adoption by sanitary authorities, and which lay down laws for the construction and arrangement of the apparatus best adapted to the requirements of health. The accompanying drawing (Fig. 357) indicates the kind of privy built on these principles, representing a receptacle of a size which is supposed to hold the amount of refuse which will accumulate in one week, and having therefore a capacity of eight cubic feet. The by-laws insist that every such privy shall have "means or apparatus for the frequent and effectual application of ashes, dust, or dry refuse to any filth which may from time to time be deposited in such receptacle." The receptacle is to be so constructed that "the contents thereof may not at any time be exposed to any rainfall or the drainage of any waste water or liquid refuse from any adjoining premises," and "of such materials and in such manner as to prevent any absorption, by any part of such receptacle, of any filth deposited therein, or any escape, by leakage or otherwise, of any part of the contents of such receptacle," and so that "the bottom or floor thereof shall be in every part at least three inches above the level of the surface of the ground adjoining such privy." The seat is to be so constructed that "the whole or part of it may be readily removed or adjusted in such a manner as to afford adequate access to such receptacle, for the purpose of removing the contents thereof, and of cleans-

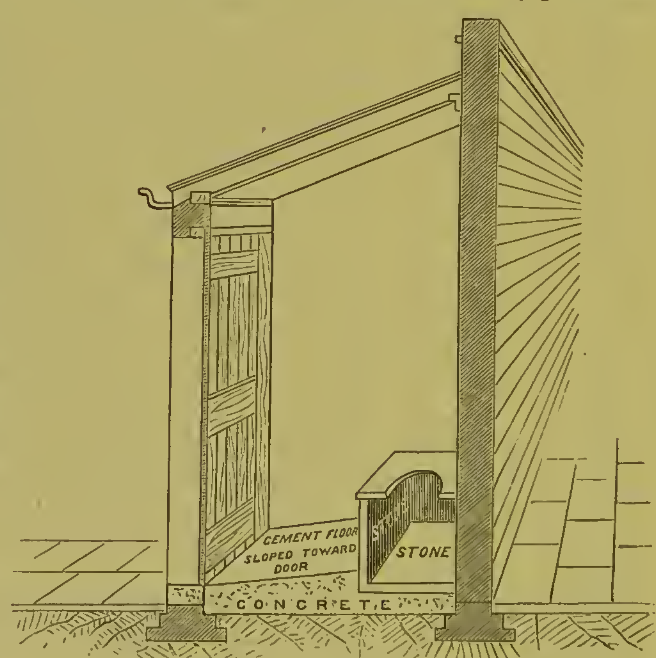

Fig. 357.

ing such receptacle, or shall otherwise provide in or in connection with such privy adequate means of access to such receptacle for the purpose aforesaid." A further by-law forbids any connection between the receptacle for filth and a drain, for reasons already explained.

The floor of the privy is to be paved with tiles or non-absorbent material, so that "it shall be in every part thereof at a height of not less than six inches above the level of the surface of the ground adjoining such privy, and so that such floor shall have a fall or inclination towards the door of such privy of half an inch to the foot." Built in this way it is impossible for any water which may be thrown on to the floor for washing it to percolate into the receptacle which holds the soil.

Other clauses require every privy to be provided with a sufficient opening for ventilation "as near to the top as practicable, and communicating directly with the external air."

Finally, the proximity of the privy is to be limited to a distance of not less than six feet from any inhabited dwelling. The situation is to be otherwise so regulated that undue proximity to a well, and the conveyance of the midden contents through an inhabited house, are prevented.

CHAPTER LXXIV.

THE PAIL SYSTEM.

The Nottingham Tub Closet — Manufacture of Manure — Construction of Pail — Goux System — Model Pail.

UNTIL now we have limited ourselves to a description of a privy which is provided with a fixed receptacle, and we have endeavoured to show what may be done to mitigate the evils with which to some extent it is necessarily accompanied. We must now turn our attention to the construction of the privy which is provided with a movable apparatus, and we will first take, as a type of that form which most closely resembles the midden, the Nottingham tub closet. It may be best described as a closet with a small movable middenstead, which is capable of being thoroughly cleansed and disinfected at frequent intervals. To quote from Mr. Netten Radcliffe's report: "It constitutes the link between the pail closet system and the midden system. The Nottingham tub closet, in fact, combines the advantages of the pail closet with the simplicity of the midden closet. The substitution of the pail for the middenstead at once obviates the various structural difficulties which beset the building of a middenstead, so as to prevent its unwholesomeness, and permits that effectual removal of the contents and cleansing of the receptacle which attach to the pail system."

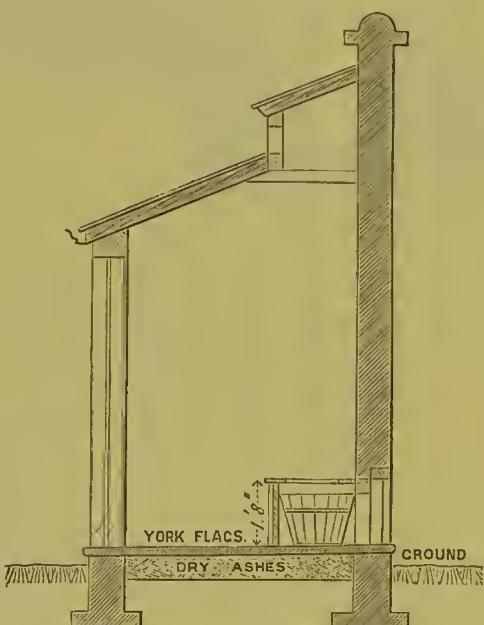

Fig. 358.

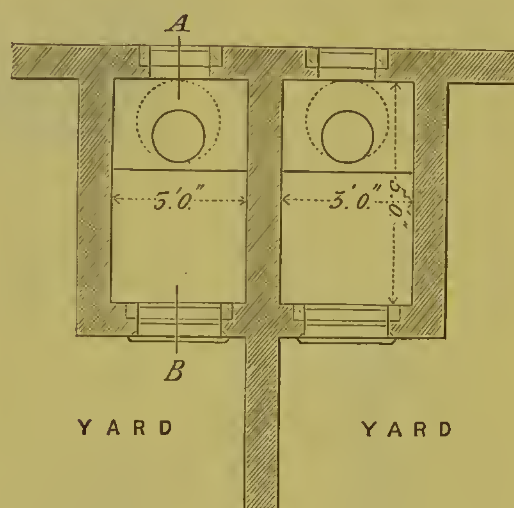

Fig. 359.

The closet is of very simple construction; in fact, its simplicity is its great merit. As the accompanying drawings (Figs. 358 and 359) show, it is provided with good means of ventilation by louvred openings in the roof. In most instances the seat is hinged, and in others the front is movable; in order to allow of the more easy removal of the tub, an opening is often made in the back wall of the closet, behind the

seat. This opening is provided with a hinged flap, which can be unlocked by the scavengers when they come to change the tubs. The tub itself is made of oak, and is kept well tarred; it has an outside diameter of 1 foot 6 inches at bottom, and 1 foot 9 inches at top, and a height of about 1 foot 4 inches; the thickness of its sides is from ½ inch to ⅝ inch, and it is covered by a metal lid. Bought as they are by contract, these tubs cost 2s. 8d. each, the whole cost of a new closet, including locks and everything, being £4. The pail is removed weekly, or at shorter intervals, according to the necessities of the case, and a clean pail is substituted for it.

It has already been said that the Nottingham pail is a small movable midden-stead. It is, in fact, used as a receptacle for solid and fluid excreta, all the solid vegetable refuse of the house, potato-peelings, &c., also the solid animal refuse, the remnants of food, &c. Together with these vegetable and animal substances, which are partly solid and partly liquid, all the dry ashes of the household are intimately mixed, so that the excremental contents of the pail are speedily covered over, absorbed, and rendered inoffensive.

The Nottingham authorities take great pains to prevent the emptying of any slops except the chamber urine into the tubs. In order to ensure this, and to prevent the tubs becoming sloppy and offensive to the users, they insist very rigidly upon good yard-drainage being provided. As we have stated with regard to middens, so also is it in every way desirable for the comfort and sanitary well-being of people that movable receptacles for the excreta should be as dry as possible; for not only is the splashing of liquid contents very objectionable to the users, but the jolting of pails full of offensive liquid along the roads in course of removal, even when this is effected by means of well-constructed covered vans, is very frequently a source of nuisance. It is these considerations which have induced the authorities at Nottingham not only to prevent, by every practicable means, the emptying of slop-water into the closet-pails, but they have also, in the case of schools and factories, objected to pails, because in such places they would be used for excreta alone without the ashes, which constitute their chief safeguard. We have already said that on sanitary grounds it is an advantage that the ordinary ash-refuse of a house should cover the midden-contents, and the same statement is equally true for the closet-pail; for in this manner not only is the liquid part of the contents absorbed and one of the chief objections to their use removed, but there is also great probability that ashes have much influence in neutralising the results of any decomposition that is going on in the pail. As a matter of fact, there is marvellously little smell about these closets, as may be proved by the experience of thousands of dwellings in Nottingham. Even in the crowded courts, where the closets are necessarily very close together, there is a notable freedom from privy nuisance. With these advantages it is natural that the system should be generally appreciated, and that it should have gained in popularity among the working classes year by year; and it is also not so much to be wondered at that the authorities have encountered no very serious difficulties in their great work of substituting tub closets for the offensive privy middens which formerly abounded in the town, and which gave rise to a great deal of preventible sickness. The sanitary authority has, until very recently, had no other powers to work with than the ordinary provisions of the Public Health Act, and, save in a few exceptional cases, the owners of property have not been subsidised; and yet,

within ten years of the time when it may be said that the tub system was on its trial, they have been able to secure its almost universal adoption in place of the privy-midden system. There are now 24,000 of these closets in the borough. Taking into account those which must necessarily serve the purpose of two or more houses, as is the case in the densely-built parts of the town, this number represents more than three parts of the population.

Just as Nottingham is abandoning the midden for the tub system, we find that in some other parts of the kingdom the same principle is guiding sanitary authorities; the fixed receptacle is giving place to the movable, but a further consideration has also an influence in determining these authorities as to the mode of disposal. With

Fig. 360.--Manchester Pail System.

them the question of converting the excreta into *poudrette*, or dry manure, has come to be of paramount importance; they have not the same opportunity of disposing ultimately of the excreta as other towns situated in the centre of an agricultural district, and they are therefore compelled to manufacture a material which can be stored in a dry form without giving rise to offensive odour, and which shall have a sufficient value as manure to enable its sale to make some return for the cost of collection, manufacture, and carriage.

Without going into details, we may mention that the process consists of the drying of the excreta in revolving cylinders, heated with steam, with the result of driving off all the fluid which is contained in the mixture which comes from the privies. An amount of sulphuric acid is also added to facilitate drying, and to fix the ammonia, and finally the manure is produced in the form of a fine powder of a brown colour, possessing a peculiar odour.

A condition essential to the value of the manure is, that nothing shall be mixed with the excreta before removal but fine ash-dust. Indeed, some authorities object, on economic grounds, to the inclusion of even this. Other solid matter, kitchen refuse, cinders, &c., must always be excluded. It becomes, therefore,

necessary where this is done, that not only should there be yard-drainage in communication with the sewers, as a means of disposing of slop-water, but that

Fig. 361.—Manchester Pail Privy.

a receptacle should be provided for the garbage and cinders, separate from that which receives the excreta and fine ashes.

In the towns, then, to which we have referred—Manchester, Salford, and Rochdale, the chief characteristic of the system is the use of a pail instead of a

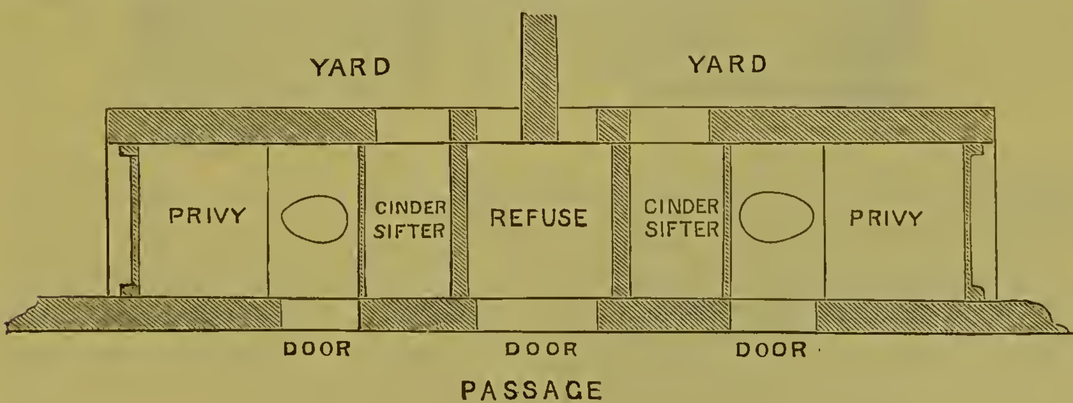

Fig 362.— Plan.

fixed receptacle, and the separation of the excreta and fine ash from the other household refuse.

Fig. 360 gives a view of a double privy seen from the house; the entrance to each privy is at the end of the building, and in the wall which faces the house openings are made, through one of which ashes may be thrown, which, falling upon a sieve, are divided into fine dust which falls into the pail beneath the seat, while the cinders fall into another pail, whence they are removed through a lower opening,

to be used again as fuel; a third opening is also provided which gives access to a tub for the reception of garbage. On the other side (Fig. 361) abutting on a passage, may be seen the doors, to which the scavengers alone have access; a central one, for the removal of garbage, and those on either side of it for the removal of the closet-pails. Thus the scavengers have no need to enter even the yard, but are able to perform the necessary duties under circumstances which cannot give rise to unpleasantness, there being no necessity for the pails to be carried through the house. The ground plan (Fig. 362) will clearly explain the relative position of the closet, cinder-sifter, and refuse-pail, together with the openings for the removal of the pails.

There is one detail that deserves especial mention, the construction of the pail. At the moment of removal the contents are liable to some amount of disturbance, and it is therefore very necessary that the pails should be provided with a close-fitting lid. In Rochdale there is one in use known as Haresceugh's patent spring-lid receptacle, the lid of which is provided with a cushion of india-rubber (see Figs. 363 and 364), which is fastened down by a strong spring. The lids are brought with the empty pails when those which are full are exchanged, and being fitted to the latter they are hermetically sealed, and all possibility of leakage or effluvia is prevented.

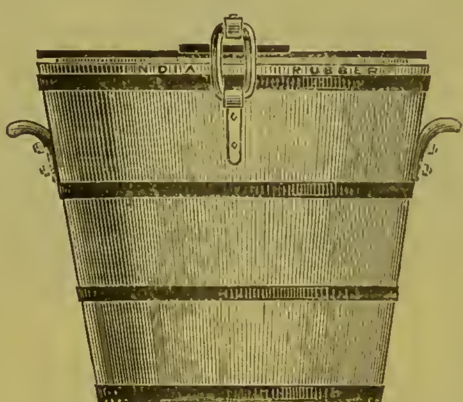

Fig. 363.—Rochdale Pail.

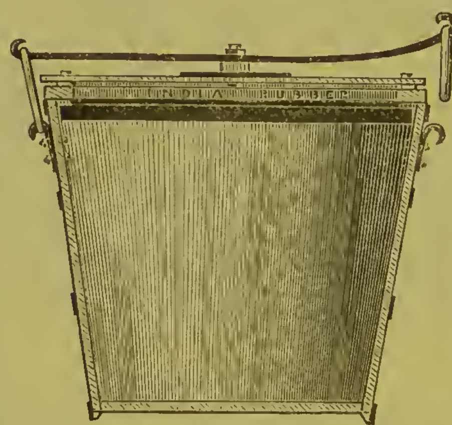

Fig. 364.—Rochdale Pail.

Rochdale, by the way, is abandoning iron pails for those of wood, finding that the latter are far less expensive, that they last longer, and are far more easily repaired.

The advantage of the use of pails over even the best constructed midden is the ease with which the removal of contents is effected. It is impossible to empty the midden without much disturbance of the contents, causing, whether by night or day, a pollution of the air; but the movable receptacle can be replaced by an absolutely clean one, while that which is full is taken to some distant spot where it is thoroughly cleansed. In Rochdale every pail is washed by water delivered from a hose at 40 lb. pressure, and is subsequently disinfected by having placed in it a small quantity of disinfectant, which is made by mixing equal parts of chloride of lime and alum in ten parts of water. Speaking of the advantages of the pail system over the old midden, Dr. Wilson, until lately the medical officer of health to Rochdale, says that since the adoption of pails there has been a marked change in the general health of the population, shown not only in lower rates of general mortality, but also in a diminution of sickness from fevers and diarrhœa.

We have but one other form of movable receptacle to describe, viz., the Goux tub. In this system also attempts are made to secure the dryness of the contents and to retard decomposition, and it has the advantage of helping to dispose of other refuse matter at the same time; but, instead of ashes being made to cover the contents, the tub is prepared in a special way, so as to render this unnecessary. The tub tapers from above downwards, is eighteen inches high and twenty inches at its greatest diameter. The bottom is covered with three or four inches of refuse, which, we are told in the trade circular of the Goux Company, may consist of "stable-litter, leaves, spent tan or hops, sawdust, shavings, shoddy, flax dressings, or the thousand-and-one convenient substances to be found in every place." This is mixed with a little soot, charcoal, gypsum, or other deodoriser. To line the sides, a mould of the same shape as the tub, but of an internal diameter six inches less, is placed upon the absorbent material at the bottom, and the space between the tub and the mould closely packed with the same refuse as that beneath the latter.

The accompanying drawings (Figs. 365 and 366) show a section of the tub charged with this substance, and the mould which is used in the filling. The preparation of the tub is not a lengthy process, and requires no special skill; one boy can pack a hundred tubs in an hour, and, when once ready for use, no other precaution has to be taken; nothing is needed but to remove the charged tub at stated times and replace it with a clean one. Only at the time of removal has anything further to be done with a view of preventing unpleasantness; but, at that moment, the part of the lining which is exposed is broken up and scattered over the surface of the contents. We have said that the intention of the lining was to secure the dryness of contents, but, as a matter of fact, it does not appear wholly to attain this object; nevertheless the tubs are remarkably free from odour, even when examined at times of the year when such matter as they contain is more likely to be offensive than at others. Mr. Radcliffe, after examining two boat-loads of the filled pails, says there was no perceptible odour from them under a hot sun, and he would not have had any suspicion of their contents either from sight or smell, had he not previously known what they were. So, again, Dr. Goldie, the medical officer of health of Leeds, says, "I would at once give it as my opinion that the absorbent packing of the Goux system answers the great end of arresting decomposition. The tubs are only emptied once a week, which would give their contents ample time to set up that decomposition which is not only most offensive to the nasal organs, but dangerous to public health." Nevertheless, he found that during a period of nearly five years, at Halifax, only two complaints had been made, and these were clearly traced to direct negligence on the part of the operatives.

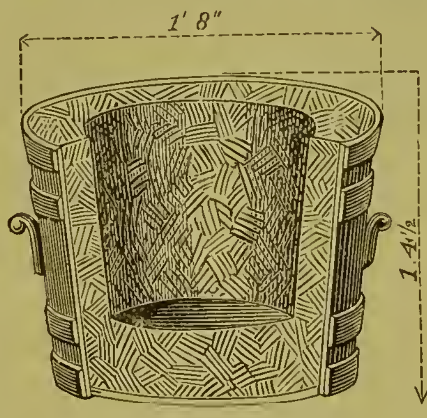

Fig. 365.—Goux Pail.

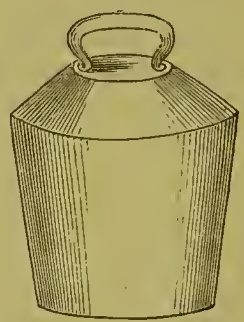
Fig. 366.—Goux Mould.

Whatever system may be adopted, the same general rules will apply to each.

It is upon the frequent emptying of pails, or rather, of the exchange of clean pails for full ones—an infinitely better plan—and the preservation of the contents in as dry a condition as possible, that success will depend.

It is essential that the pail should be impervious, and it is desirable that it should not have a larger capacity than two cubic feet. With regard to the privy itself, the instructions laid down in the model by-laws of the Local Government Board should be followed. There should be constructed over the whole area of the space immediately beneath the seat "a flagged or asphalted floor, at a height of not less than three inches above the level of the surface of the ground adjoining such privy," and the whole extent of each side of the space between the floor and the seat should be constructed of "flagging, slate, or good brickwork, at least nine inches thick, and rendered in good cement or asphalted." The pail is to be so placed that it may receive the whole of the material thrown through the seat, and so that the floor and sides of the space beneath the seat may not be polluted. The seat is to be movable, so that the pail may be changed and the space in which it stands may be thoroughly cleansed.

With regard to its situation, its distance from the house and from a well, its ventilation, and the opportunity for the pails to be changed without bringing them through the house, the same rules should be obeyed as those already described when speaking of middens.

In concluding this chapter, I ought to state that for the account of the Nottingham tub-closet I am indebted to Dr. Edward Seaton.

CHAPTER LXXV.

THE DRY-EARTH SYSTEM—GENERAL CONCLUSIONS.

Preparation of Earth—Construction of Earth-closets—Value of Earth-manure—Choice of System.

THE effect of dry earth upon excreta is very different from that of ashes, for it is found that it serves to make the excreta not only inoffensive, but to effect complete change in the latter, so that their original character cannot be recognised, and even if paper be mixed with them this disappears at the same time. We learn from Dr. Buchanan's report* that the late Rev. Henry Moule, to whom we are indebted for this method of treatment of excrement, regarded the process which takes place in the mixture "as consisting in a change of the organic substances of excrement into the state in which organic matter naturally exists in fertile soil, in such a way that the animal refuse becomes proximately available for the support of the plant, without undergoing ultimate reduction into simple salts and gases." This change is not completed immediately; it is necessary that the mixture should be kept dry for some time, as much as six weeks being as a rule required for this purpose; it then possesses the remarkable power of being able to act in the same manner as the original earth upon fresh excreta, indeed, when the earth consists of clay, it is improved by its first use. How many times it may be thus used over and over again is not quite clear, but it has been employed experimentally over a dozen times without any apparent deterioration in its power.

It is found that a pint and a half of properly-prepared earth is sufficient for each dejection, together with the urine which accompanies it. Loamy earth is the most valuable; clay is also good; sand, gravel, and chalk are practically useless. Latterly peat has been successfully used, the best results being obtained from a mixture of four parts of peat to three of earth, or earth and fine ashes in the proportion of four of the former to one of the latter. But whatever substance be chosen, two conditions are absolutely necessary: first, that the earth shall be very dry; secondly, that it shall be finely sifted. Dryness is essential at all stages of the process, for if slop-water, or leakage, lead to the mixture of earth and excreta becoming moistened, decomposition will begin, and an offensive mass be produced; there ought, however, to be no difficulty in ensuring the amount of dryness which is needed for success. The earth may be dried over the kitchen fire, or on the hearth under a kitchen range, or, better still, in summer simply in the sun. Where earth-closets are regularly used, it is well to take

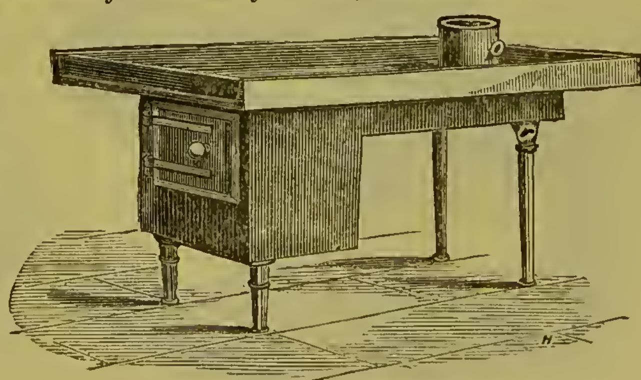

Fig. 367.—Stove for Drying Earth.

* Report of the Medical Officer of the Privy Council, 1869.

advantage of the opportunity that summer affords for the preparation of a sufficient amount of earth to last during the winter, or, if preferred, a stove such as that shown

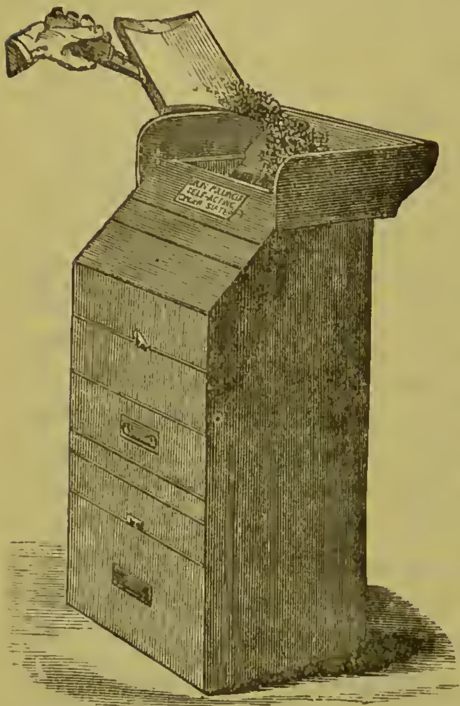

Fig. 368.—Earth-sifter.

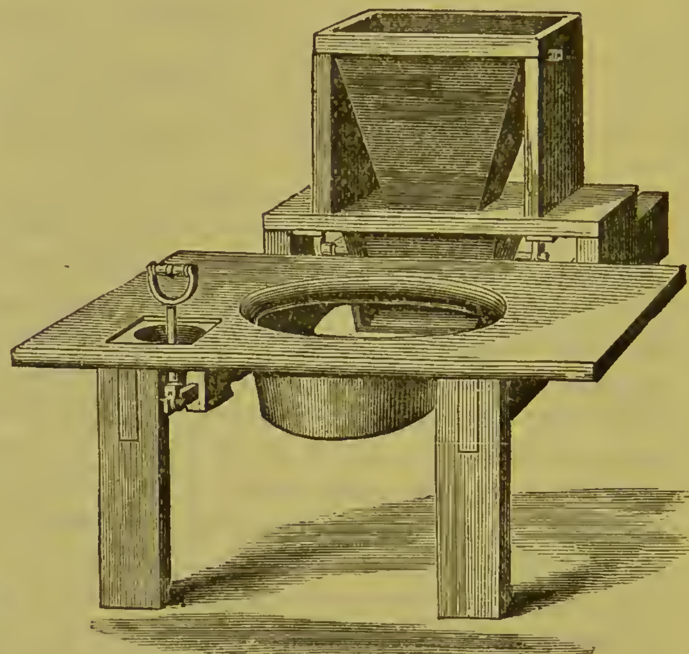

Fig. 369.—Earth Plug Closet.

in the accompanying drawing (Fig. 367) may be employed; it consists merely of a furnace with the upper surface furnished with a tray on which the earth is placed.

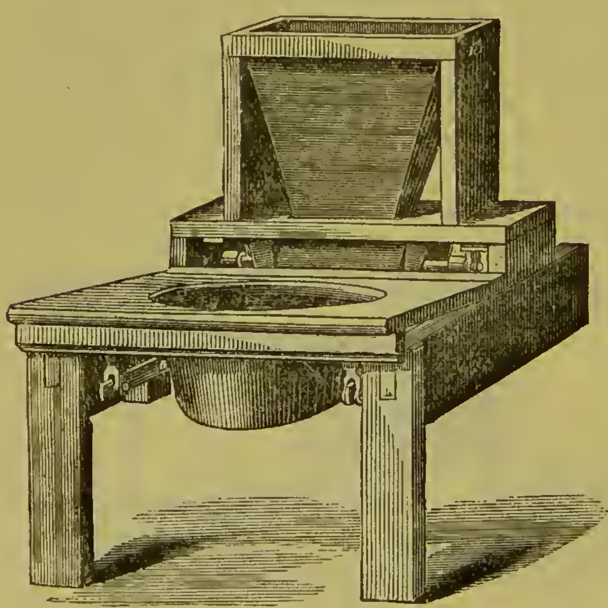

Fig. 370.—Earth Pressure Closet.

After the earth is dry it must be sifted, most conveniently by a sieve, or by means of a dustless sifter such as that shown in the annexed drawing (Fig. 368). By a simple contrivance, the earth thrown into the hopper is separated into two parts, the larger pieces passing into the lower drawer, the smaller into the upper.

It may be applied to the excreta in more than one way; by a mere scoop in the hand of the user, or by a mechanical contrivance in connection with the closet; the latter method is the better, for it eliminates any chance of improper application through the carelessness of the individual.

Mr. J. W. Girdlestone, engineer to the Moule's Earth-closet Company, has designed a closet which admirably fulfils all the necessary conditions. Fig. 369 represents one in which the earth is discharged by a plug, and Fig. 370 by pressure on the seat.

A sufficiency of earth to last for some time is placed in a hopper behind the seat, whence it falls on to a valve which holds exactly enough for one charge. The valve is connected either with a handle or with the seat, in such a manner that the pulling of the plug or the removal of the body from the seat upsets the earth on the valve into the receptacle; on again pressing down the plug or the seat, the valve is immediately charged with fresh dry earth.

This apparatus is used either in connection with a movable pail, or over a vault or fixed receptacle. Pails made of galvanised iron to hold twelve or twenty charges, and similar to that shown in the drawing (Fig. 371), are supplied with the earth-closets already described, and are found to be convenient for household use. The seat is fitted with either a galvanised iron or an earthenware rim, which, projecting below it, particularly in front, guides all fluid into the receiver. With regard to the details of construction of the rest of the earth-closet, we have little more to do than to repeat the advice which has been given for ash-closets and middens; here, also, as we have said, dryness is essential to success; for the purpose of ensuring dryness the receptacle should always be situated some two or three inches above the level of the ground, whether it be a vault or a pail, and nothing but the excreta, the urine which accompanies them, and the dry earth itself should be permitted to enter the closet. If slop-water be thrown in, the result is at once disastrous; the earth-closet, therefore, absolutely necessitates some other method of disposing of slop-water, and even of chamber urine.

Fig. 371.

The accompanying drawing (Fig. 372), shows an earth-commode well adapted for use inside the house. The removal of the contents is effected by taking out the pail in the front or the sides of the closet, and each pail is provided with a cover to be used at the time of removal. If the receptacle is placed outside the house, there is no reason why it should not be made sufficiently large to hold three months' accumulation; but if inside the house, a pail which can easily be carried is the most convenient form of receiver. It should not be placed in a bed-room or sitting-room, and wherever situated, there should be an outside wall in which there is a window to ensure ventilation.

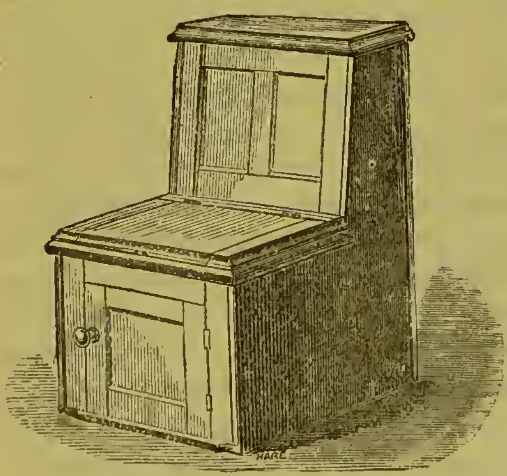

Fig. 372.—Earth-commode.

After removal from the receiver the material must be stored until the earth has had ample time to alter the composition of the excreta, and while this is taking place it must still be kept absolutely dry. Not less than six weeks should be allowed for this process to be completed, and the mixture may then be used over again in the closets, or spread over the land for manure.

Part of the advantage claimed as being derived from the earth system of excrement-disposal is the value, as a manure, of the product which is formed. In 1869 the Rev. H. Moule informed Dr. Buchanan that he had by experiment compared the earth manure with super-phosphates. "Four acres on a farm at Fordington were sown with turnips, manure having been previously drilled in; the manure to 3¾ acres was super-phosphates, bought at £7 12s. a ton; the manure on the other quarter-acre was earth compost that had been five times through closets, and bought at £3 a ton. The manures were used in equal quantity, a cwt. to each quarter-acre. The quarter-acre manured with earth compost yielded one-third more in weight of turnips than an average quarter-acre manured with super-phosphates. Sheep were fed on the turnips, and next year barley was sown over the whole four acres; the barley on the quarter-acre stood conspicuously over the other barley, and yielded area for area in the proportion of four to three over the remainder of the field." *

Similar testimony to its value has been given by some others who have used it; while in the hands of others, again, it is not credited as being worth more than ordinary garden mould. It is, on the one hand, sold at as high a price as £6 per ton, and, on the other, has been valued by Dr. Voelcker, as the result of analysis, at no more than 7s. 6d. a ton after it has passed five times through the closet. This question of the value of the product may be a matter of importance to those authorities who are looking for a return for the cost of collection and for the supply of earth; for our purposes we must consider rather its sanitary than its commercial value, and it will be well, in discussing this subject, to put aside all thought of procuring anything of greater value than a good garden mould; we shall then be left free to think only of those advantages, from a health point of view, which belong to the dry-earth system. One point, however, may be insisted upon: whatever the value of the earth may be after it has been two or three times through the closet, its subsequent use beyond this does not appear to enhance it. If, therefore, it is intended to use it over and over again, the reasons for doing so must relate only to those of convenience.

As another deodorant, we must not omit to mention charcoal, which has in ship-building communities on the Clyde come to be used in a manner similar to dry earth. The value of the method depends upon the fact that charcoal is a better deodoriser than either ashes or earth, and therefore a much smaller quantity need be used. Mr. Edward Stanford, who has especially urged the value of this material for closet use, has found by experiment that, whereas dry clay only absorbs 45 per cent. of water, dry charcoal prepared from seaweed absorbs 147 per cent. The closet to be used is practically the same as the earth-closet, but for the charcoal system it is claimed that chamber urine may be thrown on to it in addition to that which accompanies each dejection. After removal, the mixture is burnt in a retort, which distils over products which are said to have a value of a material kind, while the residue is used over again.

There are other methods by which excreta may be rendered less offensive—for instance, by the use of disinfectants—while remaining within the precincts of a house, but it is unnecessary for our purpose to do more than mention those most suitable for general use.

* Twelfth Report of the Medical Officer of the Privy Council, 1869.

CHOICE OF SYSTEM.

We have now described the different methods of conservancy adopted in various towns, and have shown how we may best contrive to render as little objectionable as possible any one we may be obliged to accept.

The midden we may regard as the most objectionable of all, but capable of improvement by reduction of its size, and by the maintenance of its contents in as dry a condition as possible; a result to be obtained by its mode of construction, and by the application to the excreta of dry household refuse.

The Nottingham tub, we have also shown, is very free from unpleasantness, owing to the thorough manner in which the excreta are covered, and to the frequency of removal, and no system can be considered satisfactory, from a health point of view, which does not provide for both. It is not, however, intended at all to convey the idea that other town authorities which have not adopted precisely the same system have failed to do the best possible thing for their communities. In some large centres of industry the authorities have had to encounter the manurial difficulty in its worst form. These towns are so large, and their surroundings are so thickly populated, that it at length came to be a matter of impossibility for them to dispose of their refuse as manure, even at a nominal price, and by sending it to great distances. Hence they have been compelled to direct their attention to the various means of reducing its bulk, and, in Rochdale and Manchester, they have now for some time been engaged in the manufacture of the material to which we have referred. For this purpose it is of course essential that the system should be different from that carried out in Nottingham at its inception; that is to say, that the closet-pail should be made to bring away only the excreta and matters of manurial value, and as little as possible of the ashes and materials which are worthless in the manufacture of poudrette. Nottingham is at present happily placed in very different circumstances, for though rapidly becoming a large town, it is still surrounded by an extensive agricultural district, and as yet there have been no serious difficulties in the way of disposing of the town refuse, except at times of frost and flood, when some accumulation takes place.

In speaking of the advantages of the pail or tub closet system, whether as carried out in Nottingham or at Manchester, it must, of course, be understood that the whole success depends on the perfection of management, by which the pails or tubs are removed and replaced in a cleanly state at regular and frequent intervals, and by which, in densely-built, crowded, poor districts, closets are regularly apportioned to houses and provided with keys. Without the most rigidly systematic arrangements, and also active and constant supervision in the poor localities of a town, the system is, of course, capable of becoming abused, and giving rise to a state of things offensive to the people, and quite as prejudicial to health as the privy-midden system. Nottingham has been fortunate in possessing a health committee who have devoted much time to this subject. The results of the improved state of things on the public health have been several times referred to in reports of the able medical officer of health, Dr. Edward Seaton. In a special paper on this subject, which he read at a meeting of the Society of Arts, in 1879, he showed that there had been a remarkable reduction in the rate of mortality and sickness from enteric fever, consequent upon the substitution of pail closets for privy-middens. It is intended to carry out still

further improvements in this direction, which, it is hoped, will be effectual in confining this disease within even narrower limits. Under the system for the "early notification of infectious diseases," which is now being introduced in Nottingham, the authorities will become acquainted with the existence of such diseases as enteric fever at once, and they will adopt special precautions. These will consist in providing special pails (coloured red) for the infected houses. The pails will be charged with a strong chemical disinfectant, probably sulphate of iron, will be removed at more frequent intervals than usual, and will be dealt with in a special manner at the wharf. It is confidently expected that by this means the death-rate from enteric fever, which has already been materially diminished, will be still further reduced.

There is, of course, no reason why the same precautions should not be taken in all towns where movable receptacles are used, and the possibility of this being done is one of the many arguments in favour of the superiority of the movable receptacle over the fixed.

Much, too, of the good results which have attended the use of the Nottingham tub is due to the way in which the dryness of contents is ensured. In Salford, for instance, as a matter of practice everything that can pass through the sieve is permitted to enter the pail. Slop-water of course is not rejected by the meshes of the sieve, and thus the pail comes under these circumstances to be far less free from nuisance than it should be.

It is not within our province to discuss at greater length the removal of this matter by the town scavengers or its subsequent disposal; but we must, in conclusion, consider the position of a house so situated that the removal of privy contents must depend upon the householder himself. Placed in a rural district, where water-carriage is impossible, and where, as we have said, the periodical removal by the scavengers of a corporation is unobtainable, we have to decide in what manner the excreta shall be treated. Under these circumstances, the dry-earth system offers the greatest possible assistance. The objections to its use in large towns—objections which consist mainly in the large amount of earth which would be required, and in the carelessness of the inhabitants in disposing of slop-water, would have no place here. In single houses, in public institutions, and even in villages, it is easy to educate people to exercise the necessary care, and then the best possible results are obtained. All that is required, in addition to the earth-closet and to the drying and sifting of the earth, is a place where the pail contents may remain until the action of the earth upon the excreta is quite complete, and this place, it must be recollected, must be one where no wet can enter.

A comparatively small plot of land will supply the earth that is required in the first instance, and the means for its ultimate disposal after use. In villages where the size of cottage-gardens is too small for each occupier to make his own arrangements, these must be made by those to whom the cottages belong. It will then be necessary to employ a man to prepare the earth and to keep the hoppers charged with a constant supply. A small kiln will be found to be useful for this purpose, and the subsequent removal of the closet contents need cause no difficulty. Farmers gladly undertake this task for the value of the manure, and are indeed generally willing to supply earth for the purpose if it is required. In the course of Mr. Radcliffe's inspection, it was only where wetness was found that complaint was made of any offensiveness. Thus, at the Adelaide Collieries, Sheldon, Bishop Auckland,

we learn the cottagers were enthusiastic in their preference for the earth-closet to the old midden closet, and more than one spoke of its greater decency and tho influence of this upon the habits of growing children; but one woman expressed a preference for tho old privy smell, and in her cottage the closet was found to be wet.

If we are able to choose that method of disposal which gives us the best promise of ensuring health, cleanliness, and decency, we should naturally select the water-carriage; but, if this be impossible, the earth system undoubtedly comes next. For the rest, we must recollect that it is not only upon the construction, but upon the use, of any given apparatus that we must depend for the prevention of injury to health; and the household must therefore be educated, wherever there are dry closets, to remember that the advantage which is to be gained from this mode of refuse-disposal ceases the very moment slop-water is permitted to enter them, whether fixed receptacles, tubs, or pails are used.

WATER.

By Professor F. S. B. François de Chaumont, M.D., F.R.S.; Rogers Field, B.A., M.Inst.C.E.; and J. Wallace Peggs, C.E.*

CHAPTER LXXVI.

THE RELATION OF WATER TO HEALTH AND DISEASE.

Quantity of Water required per head—Sources of Water-supply—Qualities of Water—Palatableness—Hardness—Impurities—Effect of Impure Water upon Health—Dissemination of Disease—Metallic Poisoning.

Water is one of the prime necessaries of life, second only to air in importance. Without air life comes quickly to an end; without water the process is slower but none the less sure; whereas without food life has been prolonged for a considerable period so long as water has been obtainable. Water used of old to be called one of the elements, before chemistry overthrew the crude notions of ancient philosophy, and it is not yet a hundred years since it was shown to be a compound body. Cavendish and Watt dispute the honour of the discovery, but like every other discovery it was led up to by the labours of others—by those of Priestly, who discovered the gas oxygen, and the existence of inflammable air, afterwards called hydrogen; and those of Lavoisier, whose brilliant discovery of the union of oxygen with other bodies laid the foundations of modern chemical science. Water, then, is a combination of the two gases—hydrogen and oxygen—in certain proportions, two parts by measure of the former to one of the latter. In chemical symbols it is commonly expressed as H_2O. One of the ancient philosophers, Thales, laid down as the principle of his school, ἄριστον μὲν ὕδωρ (water is the best), meaning thereby that water was the origin of all life. Although we now know that much of his reasoning was false, yet there is no doubt that he there recognised a grand principle—namely, the absolute necessity of moisture for all organic life. We find accordingly that the elements of water enter into the composition of everything that has life, and that, further, water, as water, is also in greater or less quantity in every tissue of both plants and animals. Everything that we eat contains water in greater or less quantity, as a reference to a table of the composition of food will at once show. Thus every pound of butcher's meat contains three-quarters of a pound of water, every pound of potatoes the same, every pound of bread about two-fifths of a pound, and so on. Green vegetables contain about nine-tenths of their weight of water, and milk and all beverages whatsoever consist for the most part of water. Looking at these facts, and still further at this one, that our own bodies are pretty nearly three parts water, it will be easily understood what an important part water plays in our existence, even if we were not convinced of it by ordinary practical experience.

* Chapters LXXVI. to LXXVIII., which deal with the matter from the Medical point of view, are by Professor De Chaumont. The subsequent chapters, treating of the Engineering aspects of the question, are by Messrs. Rogers Field and J. Wallace Peggs jointly.

Water is necessary for drinking; for cooking food; for the preparation of various beverages; for personal cleanliness; for the washing of utensils, clothes, and habitations; for removal of sewage and flushing of drains; for cleaning streets and laying the dust of roads. It is required for the use of the various animals employed by man, and for a vast number of trade purposes. It follows that the quantities necessary for different communities must vary a good deal, according as men live together in towns or are scattered in rural districts, and according as there may be or may not be systems of drainage, or trades and manufactures. We shall proceed to consider these points separately.

For drinking-purposes the amount required varies with age, sex, weight, climate, and occupation; but it may be laid down as a general rule that the total amount necessary per diem is equal to about *half an ounce* for each pound weight of the body; or, in other words, a man takes in daily about $\frac{1}{32}$ of his weight of water. Now of this water, from one-fourth to one-third exists in the so-called solid food, and the remainder is taken either as water itself, or in some other beverage or liquid food, such as beer, wine, tea, coffee, milk, soup, and the like. Supposing a man to restrict himself to water, or such beverages as are usually prepared with water, such as tea, coffee, &c., he would consume usually about half the total quantity in actual beverage, and the remainder with his food, cooked and uncooked. Thus a man, weighing say 12 stone, or 168 lb., would require daily (under ordinary circumstances of work and health) about 84 oz., or a little over half a gallon of water. Of this, in all probability, about two pints would be drunk as water, tea, or coffee, and the remainder would be present with his food in various forms. About one-half of this water is got rid of through the kidneys and the remainder through the lungs and skin. This relative proportion may be altered, as well as the actual quantity drunk, by increased muscular exertion or by increased temperature of atmosphere. In either of these two cases the action of the skin and lungs becomes considerably increased, and by the evaporation thus produced a cooling effect is obtained which preserves the balance of temperature, that would otherwise be thrown out of gear by the increased animal heat arising during the exertion. For the cooking of food a certain amount is required, only part of which is, of course, actually consumed with the food. This will generally not be less in the case of adults than three-quarters of a gallon to one gallon daily. Taking all sexes and ages together, we may lay down the minimum necessary for drinking and cooking purposes as one gallon per head per diem. This is the government allowance for soldiers in barracks, but of course much more will be used in households, where the meals are numerous and the *cuisine* more or less elaborate.

An additional quantity is also needed for washing up dishes and utensils, but this of course varies with the number used. It would probably take as much as the cooking at least, so that we may add roughly another gallon for this purpose. For house-cleaning generally not less than two gallons are necessary, so that if the cleansing of house and utensils are taken together (as is usually done in calculating) three gallons may be stipulated for.

For the washing of clothes at least three gallons are required for the most ordinary cleanliness.

With reference to personal cleanliness much depends upon the habits of the individual. Assuming, however, that each person takes a sponge-bath daily, not

less than five gallons should be allowed, the bath alone taking up about three gallons. If general baths are in use much more is required. A man weighing 12 stone occupies about three cubic feet of space, so that a bath of 10 to 12 cubic feet of capacity is not too much for him to bathe comfortably in. If such a bath is only half full it will take from 30 to 40 gallons. Thus a general bath once a week would add not less than five gallons to the daily consumption.

It will thus be seen that the least amount per head for ordinary cleanliness is 12 gallons daily, supposing the washing of clothes to be done in the house, or 9 gallons if the washing be given out; and those amounts include neither the quantity required for general baths, nor that necessary for water-closets.

Where a water-carriage system of sewerage exists, as in the ordinary water-closet, a sufficient amount of water is necessary to keep the place in good order. Some closets require more water than others, but it is generally estimated that it is not safe to allow less than five gallons per head for closet purposes. In many instances, where the use of water-waste preventers is insisted upon, there is a restriction upon the amount; some of those articles indeed deliver a quantity which is really too little for each time of use, so that the delivery must be repeated.

We may thus tabulate the quantities required as follows:

	Gallons per head per diem.
For domestic purposes, not including washing clothes or general baths	9
Water-closets	5
Amount for general baths, allowing one weekly	5
Washing clothes	3
Total about	22

This will be the amount actually used in the house, not including unavoidable waste, which may be put at about 3 gallons; but for town purposes a certain addition has to be made, in order to provide for the various things necessary, such as flushing of drains, watering streets, amount required for animals, &c.

It must be understood that the above represents the quantities necessary for fairly cleanly households, but that in many instances much less is actually used, either in consequence of difficulty in getting water, or from personal apathy and indifference. The inquiries of the late Dr. Parkes, Dr. Hassall, and others have shown that, although among the poorer and less cleanly part of the community only from 2 to 4 gallons are often used, yet among fairly cleanly persons from 12 to 20 gallons are generally required. In prisons, where one general bath weekly is the rule, about 11 gallons are used.

The quantity for animals is important when they are employed. An average-sized horse, in fair but not excessive work, will drink 6 to 8 gallons a day, and if allowed free access to water, even more. For his washing, about 2 to 3 gallons, and for the cleaning of his stable and any cart or vehicle he may draw, about 5 to 8 gallons more may be allowed. Altogether, to keep him clean and comfortable, 16 gallons should be provided. Where many horses are together less might do, and in the army the allowance is 8 gallons for cavalry and 10 gallons for artillery, the latter, of course, including the washing of the gun-carriages and limbers.

A cow drinks 5 or 6 gallons, and a sheep or pig about half a gallon to a gallon. Generally, for a non-manufacturing town, an addition of about 5 gallons has to

be made to the house supply, to allow for animals and the various town purposes already referred to. In manufacturing towns at least as much more would be required for factory and trade purposes, the amount of course being dependent on the special trades carried on. We thus have the quantities as follows:—

	Gallons per diem per head.
Requisite house supply, including waste	25
For town purposes	5
Total in non-manufacturing towns	30
For trades and factories	5
Total in factory towns	35*

Of course those amounts are supplemented to some extent by rainfall, but as it is very rare that proper provision is made for saving rain-water, its influence is only partial, and in the case of storm-waters occasionally disastrous, by bursting sewers, flooding basements, &c.

The quantities of water actually supplied in various towns sometimes exceed the above amounts, but in many cases they go below it. This means restricted cleanliness and inefficient flushing of sewers, with all their consequent evils. According to the sixth report of the Rivers' Pollution Commissioners, the average London supply was 204 gallons per house, or about 40 per head; Manchester has only 21 gallons per head; Norwich, 14½; the manufacturing towns of Lancashire and Yorkshire from 16 to 21; Glasgow, however, has 50, and Middlesborough-on Tees, 140. Manchester contemplates a vast supply in the future, to give from 50 to 60 gallons per head to its own and the neighbouring population. In some foreign cities the quantities are ample. Karlsruhe, in Germany, for instance, has 130 gallons per head, and Bonn, Hamburg, Dresden, and Frankfort have each 50 or upwards. Most of the large cities in America have also very ample supplies. Where water is used for ornamental purposes—watering gardens and parks and the like—of course a very much increased supply is required. In ancient Rome, where the public baths were of such great extent, it has been calculated that from 300 to 350 gallons per head must have been needed daily. This question of baths is of the highest importance to the health of the community, and the increase of facilities in this direction is a strong reason for desiring the most ample water-supply it is possible to obtain.

In dwellings in rural districts so large a supply as is given in many towns is not always required. If there be no system of drainage, and if the closets or privies be on a dry system, then from 16 to 20 gallons will generally suffice, with an addition for animals that may be employed. Thus, a household of five persons, with, say, one horse, would require, in round numbers, about 100 gallons a day; but if there be water-closets in use, about 120 to 130 gallons.

* It is the opinion of some who have carefully studied the question that more of this is wasted than is actually mentioned in the text, and that some economy might be effected without any detriment to sanitary requirements. In some places it has been found that from one-half to two-thirds of the water-supply has been lost by leakage of the mains, so that when the water-supply was thirty gallons the actual amount used in the houses was not more than twenty, and in some cases much less. By introducing proper waste-detectors economy of water might be accomplished, whilst the full amount for hygienic requirements might still be given to the consumer. See report by Mr. G. Deacon, of Liverpool.

SOURCES OF WATER.

All the water on the earth is originally rain, the character of which is altered by the place in which it falls, and the various media through which it passes. There is continual evaporation going on from the surface of both land and sea, and the water thus evaporated is ultimately returned to the earth as rain, dew, mist, &c. It has been calculated that the evaporation from the surface of the tropical seas is equal to 100 inches a year—that is, from every square inch of surface 100 cubic inches rise into the air as vapour. When we thus speak of cubic inches of water it does not sound a very large quantity, but if we reduce it to gallons or tons from a given surface, we get a better idea of what it means. A gallon of water measures, in round numbers, 277 cubic inches, so that $2\frac{3}{4}$ square inches of a tropical sea gives off a gallon of water as vapour in the year. A square foot in this way would yield 52 gallons, a square yard 468, and an acre more than $2\frac{1}{4}$ millions of gallons. When we consider that there are 640 acres to the square mile, and that the ocean occupies many millions of square miles, we get a faint glimpse of the enormous amount of water which is perpetually rising into the atmosphere and being again deposited. In the British Isles the average rainfall in the year may be taken at about 30 inches on each inch of surface, or over 3,000 tons of water to the acre. Now there is in the United Kingdom an average of only one person to $2\frac{1}{4}$ acres, so that if we allowed every individual 100 gallons a day, there would be, from rain alone, enough to supply a population *forty* times as great. Of course there would always be a great deal of unavoidable waste, but still this shows that, with proper management, we need never fear any failure in our water-supply.

Rain-water, if carefully collected, is the purest natural water obtainable, but it invariably contains some substances taken up from the atmosphere, such as atmospheric air itself, a little chloride of sodium or common salt, a little ammonia and nitric acid, particularly after thunderstorms. There is also some organic matter and some suspended matter, such as fine particles of dust, pollen of flowers, and many other things. When rain is collected in or near towns, or off house-roofs and the like, there is of course much soot, as well as various other impurities, and near the sea the salt is often in large quantity.

Rain-water is very soft, owing to the absence of salts of lime and magnesia; it is, therefore, good for washing and cooking purposes, although it is less palatable than other kinds for drinking.

River-water varies very much in its composition, according to the nature of the ground it flows through. It always contains much more solid matter than rain-water, and it is indeed the action of rivers in washing out the soluble mineral matter from the soil that produces the saltness of the sea. The salt is being continually carried into the ocean—the water evaporates, but the salt remains. River-water is generally good and palatable, unless sewage or other impurities are allowed to get into it.

Spring-water is generally looked upon, and justly so, as the best kind of water for most ordinary purposes, certainly for drinking, although rain-water may be better for washing and cooking if the spring-water be hard. Springs are merely the outflow of underground reservoirs of water at a greater height; or they may be the outflow of lakes or other elevated sheets of water. In either case the water

seeks its own level, or is pressed out by the constant development of gases, as probably happens with some mineral springs. Spring-water from deep sources is usually free from dangerous impurities, as the source from which it comes is generally protected; or, if not, the passage through the earth filters it to a great extent. Of course its composition varies with the strata from which it comes.

Wells are of different kinds—shallow wells, deep wells, and artesian wells. The water from these varies greatly. A shallow well is one which is either of slight depth, not exceeding 20 or 30 feet; or, if deeper, sunk only in the uppermost permeable stratum. Under those circumstances it is exposed to be contaminated with all the impurities at or near the surface of the ground. The water of such a well is always looked upon with great suspicion, more so even than that of a sewage-contaminated river, for in the latter case there is a certain purifying influence caused by the flow of the stream and its constant exposure to the air.

Deep wells, from 50 feet downwards, are generally good sources of supply, at least if they penetrate through one or more impermeable strata, such as rock or stiff clay; but if there be no such stratum, the well to be safe ought to be deeper still.

Artesian wells are artificial springs, made by boring deep into the ground, until a layer of water is struck which at some part has a higher level; the water rushes

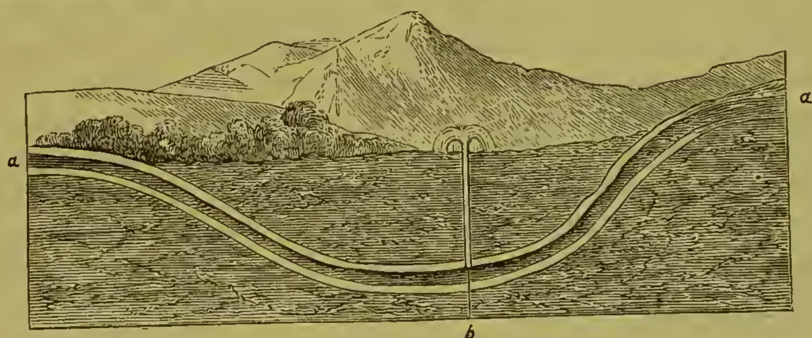

Fig. 373.—Theory of Artesian Wells.

up to the surface, or at least to the level of its highest point. From the great depth of such wells, the water is generally free from any dangerous impurity. It is sometimes hot, however, and is nearly always badly aërated, and consequently not very palatable until after some exposure. Fig. 373 shows the theory of an artesian well; *a*, *a*, is the stratum of water struck at *b*, whence the water rushes up to the surface, seeking its original level.

The characteristic composition of water from different strata, whether it be obtained from river, spring, or well, depends upon the amount of soluble material in each stratum itself. Thus primitive and metamorphic rocks, such as granites, gneiss, trap, &c., contain very little soluble matter, and consequently the water from them is very pure, always supposing accidental impurities are absent; that is, impurities caused for the most part by the carelessness of man himself. Clay-slate and clay yield very little to water, and sometimes are useful as barriers for keeping out other impurities. Sands and gravels yield pure water, so long as they are not artificially contaminated. All those waters are usually comparatively soft; water from sandstone strata often contains a good deal of salt; limestone and chalk strata yield the hardest water. If the hardness is due to carbonate of lime (or

chalk) it is of little consequence, for it is not unwholesome, and it can be removed to a large extent by simple boiling; but if the hardness is due to other salts of lime, such as the sulphate (which is gypsum, or plaster of Paris), then it is objectionable, and cannot be got rid of by boiling. Magnesian limestone, or dolomite, yields more or less magnesian salts to water, and these are always to be avoided.

Water, particularly surface-water, from alluvial soils, marshes, and cultivated lands, is generally more or less charged with organic matter, which is often of a dangerous character.

QUALITY OF WATER AND SOURCES OF POLLUTION.

Water may be considered with reference to the following characters:—1. Its palatableness or otherwise; 2. Its hardness; 3. Excess or otherwise of common salt or substances that do not give hardness; 4. The amount of dissolved organic matter; 5. The amount of turbidity and sediment; 6. The presence of metallic poisons.

1. *Palatableness of Water.*—We are accustomed to speak of water as being pleasant, bright, sparkling, and so on; or, on the other hand, as flat, tasteless, insipid, or the like. It is a common notion that the taste is due to the salts or other solids dissolved in water, but this is quite an error. Indeed, we may confidently say that when those substances can be tasted it is high time to look out for another supply. In some experiments which I made a number of years ago, I found that it required the following amounts to be present in a gallon of water before they could be distinctly tasted:—Chloride of sodium (common salt) 75 grains; calcium carbonate (chalk) 10 to 12 grains; calcium sulphate (gypsum, or plaster of Paris) 25 to 30 grains; magnesium chloride, 50 to 55 grains; sodium carbonate (common washing soda) 60 to 65 grains. All these, except the chalk, are very large quantities, much larger than are at all desirable in our drinking-water. There is only one class of substances among solids which is detectable by taste in small quantities, and that is the metals, such as iron, zinc, &c.—so small a quantity of iron as $\frac{1}{5}$ of a grain in a gallon giving a distinct taste to water. But the pleasant, sparkling taste, associated with good water, is really due to the gases contained in it, particularly atmospheric air itself and carbonic acid gas, which last is the gas which gives the effervescence to aërated waters. The existence of gases in water can be easily observed when a glass vessel of water is allowed to stand for a little time, especially in a warm place. If it be a well-aërated water, bubbles of gas are soon seen to collect at the sides, whereas a vessel of distilled or flat water does not show the same sign. Many people think if water tastes well, it is enough to establish its claim to wholesomeness. No doubt the best waters are agreeable to drink, and we may also admit that a well-tasted water has a greater chance of being good and pure than a less palatable one; but it is a dangerous fallacy to suppose that the test is one to be implicitly relied upon. It sometimes happens, indeed, that the very sparkling character of the water, which is its chief attraction, is due to the gases given off in organic putrefaction. It has not unfrequently occurred that very impure water has been much sought after on this account, as the history of some of the notorious London pumps could tell. The following table from the report of the Rivers'

Pollution Commissioners is a good example of how palatableness may co-exist with impurity.

Wholesome	1. Spring-water 2. Deep well-water	Very palatable.
	3. Upland surface-water	Moderately palatable.
Suspicious	4. Stored rain-water	
	5. Surface-water from cultivated land	Palatable.
Dangerous	6. River-water, to which sewage gains access 7. Shallow well-water.	

It will thus be seen that the two most dangerous kinds of water are really more palatable than one of the best kind. We must, therefore, draw the conclusion that, although taste is a guide to some extent, it is by no means safe to rely on it.

2. *Hardness of Water.*—This quality is well known and easily recognised: a hard water gives a rough feeling, or a sensation of resistance, when the fingers are moistened with it and rubbed; it is also difficult to dissolve soap in it. On the other hand, a soft water is smoother to the touch and dissolves soap easily, the difficulty really being to get rid of the soap when washing in it. Hardness is caused by the presence of salts of lime or magnesia, or by any free acid. The only free acid usually present is carbonic acid, which helps to keep the chalk in solution that may be in the water. Hardness is divided into Fixed hardness, and Temporary or Removable hardness. Fixed hardness is due to any salt of lime, except the carbonate, generally either the sulphate or the chloride, and any salt of magnesia; such hardness cannot be removed by boiling or any other practicable process. Temporary hardness is due to the carbonate of lime (chalk) kept in solution by the free carbonic acid; such hardness can be almost entirely removed by boiling, or by getting rid of the free carbonic acid in another way. Boiling drives it off, and the chalk can no longer remain dissolved; on the other hand, if we add just enough of lime-water to combine with the free carbonic acid and form some additional chalk, we achieve the same end, and so, by an apparent paradox, get rid of a lime-salt by adding more lime to the water. The effects of boiling may be easily seen when a chalk water is boiled, as it quickly gets milky-looking; deposits, too, form rapidly in kettles and boilers, and sometimes give a good deal of trouble.

The disadvantages of hard water are numerous, as it is bad for cooking, for making tea, and for washing, and in most cases unwholesome for drinking. As regards cooking, it is particularly bad for cooking vegetables, which are seldom good when boiled in hard water. Tea does not infuse properly in it, and to overcome this difficulty housekeepers frequently put a pinch of carbonate of soda in the pot. This counteracts the hardness, but it spoils the flavour of the tea; for it neutralises the acid, upon which much of the taste depends, and it favours the solution of the coarser colouring and extractive matters, which give a rough taste even to the best and most delicate teas. But it is especially in washing that there is waste and loss, a considerable quantity of soap being expended before enough dissolves in the water for the purpose. The hardness of water is calculated according to the number of grains of chalk in a gallon; or, if the hardness be due to other salts than chalk, it is reckoned as equal to a proportionate amount of chalk. Thus a water of ten degrees of hardness (on what is known as Clark's scale) means that it would waste as much soap as ten grains of chalk would if dissolved in one gallon of water. Now every grain of chalk (or degree of hardness) wastes about *eight* grains of soap, a small

amount taken by itself, but if it be multiplied by hundreds of thousands it soon mounts up to an appreciable quantity. We saw before that the average minimum for clothes-washing per head was three gallons daily, and if to this we add as much more, to represent personal washing and any other cleansing requiring the use of soap, we have thus six gallons per head per diem. Suppose the water to be of ten degrees of hardness; this would waste 80 grains of soap per gallon, or 480 for the six gallons. This in one year would represent 25 lb. of soap, or for each household of five persons 125 lb. of soap simply wasted in each year. But the amount of hardness supposed is by no means the extreme, for I have analysed waters in actual use with at least six times that amount; in such a case the waste for each household would reach 750 lb., or one-third of a ton, in every year. The disadvantage of hard water, in this respect at least, must be very evident. The saving in the City of Glasgow alone, resulting from the use of the soft Loch Katrine water instead of the previous harder supply, was estimated at £36,000 per annum.

The effect of hardness upon health has been disputed, some insisting that a certain amount of lime and magnesia salts in drinking-water is good for the nutrition of the body; others holding an opposite view. It is possible that some of those salts may be utilised in that way, but it is much more probable that they are supplied through the food. That they are necessary is unquestionable, but the moot point is the desirability of the drinking-water being the medium through which they should be given. There is, on the other hand, evidence that hard waters produce dyspepsia, and that if there is much magnesia diarrhœa may be produced. This also occurs with the waters containing gypsum, and was one reason why the Paris water used to affect strangers so often. This is not so much the case now, as the supply has been to a large extent changed and much improved. Hard water has also been believed to produce gravel and stone in the bladder. Swellings of the glands (or kernels) have been traced to it, especially if the hardness be largely due to magnesia. Thus, goitre is met with in countries where magnesian limestone abounds, and it is said that in some parts of France conscripts have succeeded in producing a temporary swelling of the glands of the neck by drinking hard water, in order to escape military service. The effect is sometimes produced in eight or ten days. In the gaol at Durham swellings of the neck appeared when a certain water, very hard, was used; they disappeared on a purer and softer water being issued. Hard water is particularly undesirable for young children and invalids.

Taking advantage of the fact that the greater part of the hardness due to chalk is removable, by the addition of a proper proportion of lime, an ingenious method was patented by the late Dr. Clark, and since improved by others, by which the waters from chalk and limestone districts can be greatly softened. This plan (the addition of lime-water as before mentioned) is now employed on a large scale by several water companies, and it is well worthy of general adoption. The process is, however, applicable only to carbonate of lime, or chalk hardness.

3. *Excess of Common and Other Salts that do not give Hardness.*—The salts which do not give hardness to water are sodium chloride (or common salt), potassium chloride, ammonium chloride (sal ammoniac), sodium and potassium carbonates, and sometimes a little nitre. Of these the common salt and the sodium carbonate (common soda) are much the most common; indeed common salt is found in all water whatsoever, except distilled water. When it is in great excess, sufficient to

be tasted, the water is said to be brackish, and this may arise either from mixture with sea-water, or from saline strata. It is almost invariably associated, under those circumstances, with hard salts, which are in themselves objectionable. Brackish water ought not to be used, although people not only use it but get to like it. In some of the South Sea Islands the natives are even said to drink sea-water, and the ancient Romans are said to have sometimes mixed their wine with sea-water. This may, however, have been with a medicinal intention, as we take mineral waters in the present day. Brackish waters are dangerous for young children and invalids, especially when there is any disorder of the bowels, as they both produce and aggravate diarrhœa. Of the importance of chlorides with reference to sewage we shall speak farther on.

Water containing a good deal of carbonate of soda is sometimes met with; it is slightly alkaline and consequently soft, and it is not likely to be injurious.

4. *Organic Matter in Water.*—This is a much more important question than those we have just considered, because the effects of organic matter under certain circumstances are most serious, not infrequently leading to disastrous outbreaks of disease. It is not, however, every kind of organic matter that has this effect. The organic impurities of water may be divided into vegetable and animal, and perhaps also into organised and non-organised. An organised substance is one that has a definite structure and life of its own, often capable of reproducing its species in favourable conditions. It is still a doubtful point whether such substances can really exist in solution, or are only present as suspended matter or sediment. The division into vegetable and animal is, however, simple enough. Vegetable matter is probably present to a greater or less extent in all waters of a natural kind;

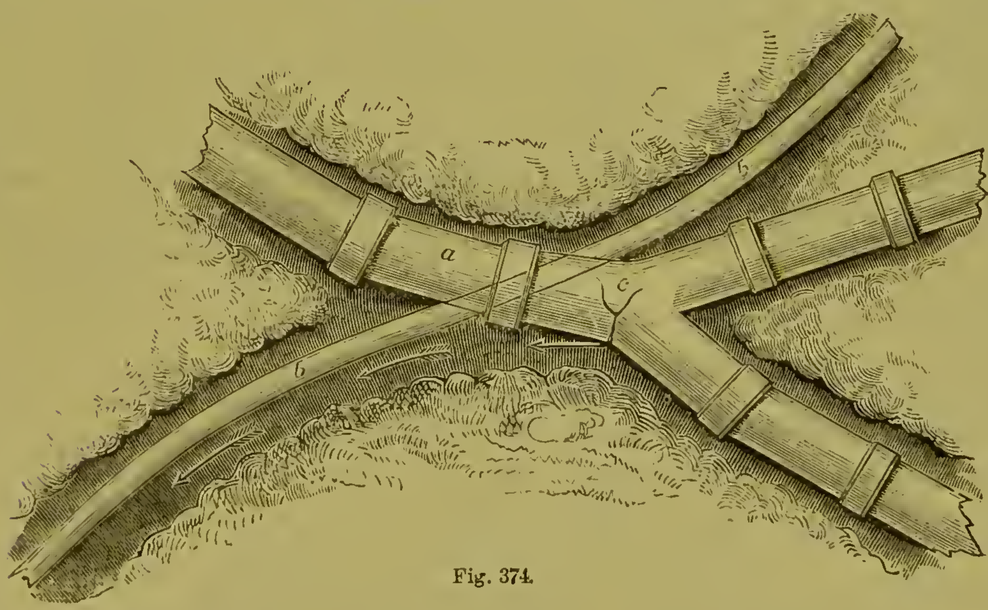

Fig. 374.

it is hurtful in some cases where the matter comes from plants of an acrid kind, but this, although not uncommon in hot countries, is rare in our land. When the matter is from marshes, however, it is often distinctly hurtful. But in many cases the water is from peat or moorland, and then the vegetable matter is for the most part harmless. A large part of the water-supply of Ireland is from this source.

Animal matter, on the other hand, is almost invariably hurtful, even when we are unable to trace positive specific disease to its influence. By far the most common source of such impurity is sewage, which may get into water in various ways, by soakage from cesspools or leaking drains getting into wells, by sewage poured into streams and other sources of water-supply, or by contamination within the dwelling itself, through closets, sinks, and the like. Fig. 374 is a good instance (drawn from an actual case) of how a leaking drain may contaminate a well: *a* is the drain, which has broken at *c*: *b b* is the pipe leading from the well to the house-pump; the direction of the arrows shows the course taken by the sewage from the leak, along the channel in which the pipe lay, into the well itself. Those points will be referred to more in detail farther on. Another, but less common, origin of organic matter is when bodies or portions of bodies of human beings or animals get into the supply. Rats, mice, birds, &c., not infrequently get drowned in wells, tanks, and cisterns; and even larger animals, such as dogs, cats, pigs, sheep, &c.; and occasionally human beings find their way in. It may also happen that the drainage of graveyards, slaughter-houses, &c., may find access. All these conditions are very dangerous, and ought to be guarded against as much as possible.

5. *The Amount of Turbidity and Sediment.*—Water is often turbid, and sometimes extremely so, particularly after heavy rains. If the suspended matter is merely mineral, such as fine particles of sand, clay, &c., it is of comparatively little consequence, as it soon clears itself, and the water may be good after that. But in many, nay, in most instances there is a large amount of organic matter of different kinds present, including many living organisms. The water may or may not be good then, according to the nature of the objects present. Mere vegetable matter is generally harmless, although it may sometimes exist to an extent sufficient to kill fish. This happened recently in a stream in Ireland, from a sudden discharge of peaty matter, from the bursting of a bog; but in such a case it is probably a case of suffocation, caused by the vegetable matter adhering to the gills and preventing respiration. But where we have to do with animal substances we find the dangers greatly increased, especially when they are particles from the skin and bowels thrown off during disease. It is not unusual to find portions of partially-digested food, such as muscular (or flesh) fibre, along with starch-cells and epithelium, or the peculiar cells that cover the mucous membrane of the mouth, gullet, bowels, &c. The epithelium of the skin, a very indestructible substance, is also frequently found. On the whole there is a growing belief that the suspended matter in water is really the most dangerous, and that one of the first requirements for a good water is clearness and freedom from marked colour. Another source of turbidity arises from the drainage of manufactories, but this is now to a large extent prevented by recent legislation. A good deal of importance has been attached to the presence of living organisms in water, and it has sometimes been thought that it indicated that the water was not fit for use. There is, however, but little evidence in this direction; indeed, it is generally found that in dangerously impure waters the higher forms of life, such as the water-fleas, worms, &c., will not live, and consequently they are either absent or only their remains are found. Although some of the microscopic forms are found under suspicious conditions, we are still much in the dark on the subject. Remembering, however, the lesson taught by an aquarium,

that the water remains clear and wholesome so long as a due balance of animal and vegetable life is maintained, we may assume that the same takes place in the microscopic world of a drop of water as in the grosser visible one of the aquarium. If, therefore, the creatures and plants observable are healthy and vigorous, the water will generally be innocuous; whilst, on the other hand, in really bad water, the organisms are often found colourless and starved. Still our drinking-supply is better without them at all, and it ought to be delivered sufficiently filtered to be free from them.

With reference to the colour, apart from turbidity, it may be mentioned that the best waters, looked at through a depth of two or three feet, are colourless, or at most slightly bluish in tint; water containing vegetable matter is generally greenish, except in the case of peaty matter, when it may be yellow, going into brown. Water containing animal matter is generally yellow; but yellowness may be due, as we have seen, to peat; or it may also be due to a little iron. *Colourless* or *bluish* waters are, therefore, the best; *yellow* the worst, unless we can trace the colour to iron or peat; *greenish* are for the most part harmless, although they may sometimes be objectionable.

6. The question of *Metallic Poisons* will be considered farther on.

There is hardly any method of determining the presence or absence of impurities, except by the microscope and by quantitative chemical analysis, both of which are beyond the scope of ordinary persons. The presence of chlorine in any marked quantity is, however, always a ground of suspicion, unless it can be traced to salt from the sea or from saline strata. This may be detected by adding a few drops of solution of nitrate of silver (lunar caustic) made acid with a little dilute nitric acid. If only a little chlorine be present, a slight bluish haze will be formed; but if there be much it will become dense, going on to a curdy white precipitate, which is soon discoloured by the light. Another plan may roughly detect organic matter. If a little Condy's fluid is put into water, the water ought to remain pink for some time, but if the colour rapidly disappears it indicates an excess of organic matter. Both these tests are, however, very rough, and not much to be depended upon, except in the hands of a practised chemist. The best way of estimating for the general public is to attend to the physical character of the water, embracing the following chief points:—

1. The water must be clear, and entirely free from sediment or suspended matter.

2. It should be colourless or bluish, if looked at through a depth of two or three feet. Greenish waters are not generally hurtful; yellowish or brownish waters are to be looked upon with suspicion, unless the colour is known to depend on peat or iron.

3. The water should be bright and sparkling, showing that it is well charged with air and carbonic acid.

4. It should have the pleasant, sparkling taste of good water, but no brackish or any other unpleasant or peculiar taste.

5. There should be no smell, other than the peculiar, indescribable (ozonic ?) smell which fresh spring-water yields.

6. The water ought to be soft to the touch, and to dissolve soap easily.

Although it is impossible to guarantee that such a water shall be absolutely free

from danger, yet we may go so far as to say that no water can be a first-class water where those qualities are absent; and also, that, if they be present, the chances are very greatly in favour of the water being a good and wholesome one.

EFFECTS OF IMPURE WATER UPON HEALTH.

The impurities in water being very various, it may easily be understood that their effects vary in proportion. Generally speaking, if a sudden outbreak of disease occurs in a community, it may be confidently referred to either the food or the water. The former is a rare cause, as it is not often that a whole community has food from exactly the same source; but the water-supply is frequently the same for all, and that being the one thing common to all, it is reasonable to refer to it as the probable cause. In many instances investigation has borne out this view, as will be noted presently. It must, however, be further pointed out that there may be, and doubtless are, effects of a more gradual and insidious nature, which are produced by the prolonged use of impure water; and that, therefore, the argument that the water has not yet done any harm is a very lame excuse for its continued use. It took a long time before it was understood that a continual breathing of foul air was one of the main causes of consumption, yet even now it is difficult to make people understand the fact. In the same way it will doubtless be found that the continued taking of small quantities of impurity in water may furnish the explanation of much unhealthiness that at present puzzles both physician and patient. It is, however, beginning to be admitted that, even where nothing positive can be proved in this matter, it is a bad preparation for withstanding the attacks of disease to drink contaminated water. When disease-poison does get access to the water, it is apparently more than ordinarily virulent, and acts upon the consumers of the water with greater rapidity and certainty. Our aim ought to be to get the purest possible water at all times and under all circumstances, and not to trust to chance to save us from the effects of our own neglect.

Let us now consider some of the chief diseases likely to be induced by the medium of impure water. These are, diarrhœa and dysentery, typhoid (or enteric) fever, cholera, and ague; also dyspepsia and some other affections; parasites of different kinds; metallic poisoning. There may be others, but with respect to them the evidence is at present either imperfect or altogether wanting.

Diarrhœa.—This disease is a very common one, and very fatal to both children and old people. It is most frequent in summer and autumn, and has been attributed to indulgence in unripe fruit, &c. No doubt there is more than one cause of it, but water plays no inconsiderable part among them. The disease may be induced both by animal and vegetable organic matter, and by mineral matter as well. Sometimes it is produced mechanically, as has been seen when irritating suspended matter has been present in the water. In the hills of India, for instance, the so-called hill-diarrhœa has been found to be caused, in some cases at least, by minute scales of mica floating in the water. At other times it may be produced by the dissolved mineral salts, especially salts of magnesia, which are purgative in very small quantity.

In some rivers, such as the Maas in Holland, the Mississippi and the Missouri

in America, and the Ganges in India, a large quantity of suspended matter is brought down by floods at certain times of the year, and then the water is apt to produce diarrhœa. Hard and brackish waters (as already mentioned) are apt to produce diarrhœa, especially when there is much magnesia or gypsum in them. Vegetable matter, though generally believed on good grounds to be harmless, may produce diarrhœa. A case in point is noticed by Professor Wanklyn at the Leek workhouse. The most common cause, however, is animal impurity, chiefly sewage. At a school in the neighbourhood of Winchester a severe outbreak of diarrhœa was traced to the bursting of a drain into the well. This accident, and the leaking of cesspools, has brought on the disorder in several cases under my own observation. At the barracks at Kingsale an outbreak of diarrhœa was traced to the foul condition of the well-water; on the well being cleaned out the disease ceased. In some cases the water in cisterns gets contaminated by the air from a sewer or privy rising up through the water or discharge pipe. A case of this sort happened in a public institution in Southampton, causing severe diarrhœa before the cause was detected. Dr. Greenhow cites a similar case in Mr. Simon's second report. Diarrhœa has also been caused by the bodies of rats, birds, cats, &c., getting into wells and cisterns and putrefying there.

Dysentery, which used to be so common and fatal in England, has long ceased to be so, but it makes its appearance from time to time, and it is well to know that the disease is capable of being excited and aggravated by the use of impure water. This has been often noticed among troops in foreign stations and in the field, although its occurrence at home is now rare.

Typhoid Fever, or as it is now very frequently called, *Enteric Fever*, is one of the most fatal diseases that we have to deal with in this country. Its ravages are not so startling as those of cholera or plague, but the death-rate from it is constant, and amounts to far more than that of those other more startling diseases. The deaths in the year reach from twelve to fifteen thousand in England and Wales alone: this averages about 120,000 persons attacked, who are disabled for at least a month or five weeks, and left debilitated and damaged for a much longer time. There is not only much danger to life, but also a great amount of loss of valuable time, which in too many cases means want and misery to those dependent upon the victims. It would answer no good purpose to go in any detail into the vexed question of the cause of the disease; it is sufficient to say that the majority of inquirers recognise the probable existence of a special poison, and that this poison is chiefly found in the bowel evacuations of the affected person: that this poison may be propagated in more ways than one, but that the two most frequent are through air and through water—in the one instance by sewer or cesspool air being breathed, and in the other by water contaminated with infected sewage being swallowed. Both ways are only too common, but probably the more generally severe and fatal is through water, as the sufferer in this way gets a more concentrated dose of the poison. Water contaminated with ordinary sewage may give diarrhœa, but will not give typhoid fever. Of course it is difficult to be certain in each case that a typhoid stool has never passed into the polluting sewage, but we have cases of this sort: in some places water has been used for years without producing typhoid fever, although known to be contaminated with sewage, but soon after the introduction of a case from without the disease has spread with rapidity. A remarkable instance

of this sort took place at Nunney (reported by Dr. Ballard), where polluted water had been in use for years without fever; but after a case had come into the village seventy-six persons out of 832 were attacked, the attacks being confined to those who drank of the water of the stream into which the typhoid discharges passed. In the school in Hants, before cited, diarrhœa occurred in consequence of ordinary sewage getting into the well; but after a case of typhoid fever was contracted outside, the disease spread rapidly and fatally through the school. In the village of Terling, in Essex, a very severe outbreak of fever was traced to the contamination of the wells; the connection between the cesspools and the wells being, by the carbolic acid poured down the privies, soon perceived in the well-water. The influence of foul water has been shown very well in the history of Millbank prison, in which the disease was common up to 1854. Up to that time the water-supply was taken from the Thames nearly opposite the prison, but in 1854 the artesian well in Trafalgar Square was sunk, and the water-supply taken from it. From that time till the present no case of typhoid fever has occurred within the prison walls that has not been imported from without. Mr. Simon has carefully drawn up statistics of a large number of cases of typhoid fever, in which he has shown that foul air or foul water has been present along with all of them. In a case in which I analysed the water the disease was apparently traceable to the contamination of the supply through the overflow-pipe of the cistern, which passed directly into a sewer.

A very remarkable case was investigated a few years ago by Dr. Thorne Thorne at Caterham and Redhill, Surrey. The Caterham Water Company found that they were unable to supply their whole district with their existing arrangements, and in the more remote part of the district they were obliged to get part of their supply from a neighbouring company. In the meantime they determined to enlarge their sources of supply by digging additional wells, and cutting and enlarging the adits from one to the other. Careful arrangements were made to prevent contamination of the water during the work, and the men were instructed always to ease themselves before descending into the works: should any man, however, find it necessary to do so whilst in the works, he was instructed to make use of one of the buckets in which the rubbish was carried to the surface. One of the workmen, newly taken on, was suffering, unknown to himself, from a mild attack of typhoid fever, accompanied with diarrhœa; and he confessed that he was obliged not only to have resort to the buckets, but even to make use of the adit itself on emergency. About twelve or fourteen days after he began to work, typhoid fever began to show itself among the consumers of the water; the disease spread rapidly, and about 350 cases with several deaths took place. When Dr. Thorne Thorne investigated the circumstances, one remarkable fact became evident—viz., that the disease was almost entirely confined to that part of the district supplied with the company's water pure and simple, whilst the outlying part, which was only partially supplied from the company's wells, but whose chief supply was from those of the neighbouring company, remained nearly free from the disease. This fact, joined with the other that the disease broke out just about the usual time after the workman must have been the cause of contaminating the well, pointed clearly to the Caterham company's water as the medium of contagion. Another corroborating fact was that at the Lunatic Asylum, where the water-supply was from a deep well on their own premises, the inmates remained free from the

disease, and at the barracks the Guards, who also drank the water of the asylum well, did not suffer. The latter was a pure water, as I had an opportunity of analysing it myself. The remedial measures adopted were to stop the supply of water at once, to pump the wells dry several times, to scrape the sides of the wells and the adits and wash them with chloride of lime, and to throw large quantities of Condy's fluid into the water. From that time the disease entirely ceased. No more marked proof could be given of the transmission of the disease through water.

At Cowbridge in Wales a remarkable outbreak took place some years ago. Out of 90 to 100 persons who attended a race ball at the principal inn there, more than one-third were shortly laid up with fever. "In this case," says the late Dr. Budd, "there was satisfactory reason to think the water contaminated, though there was no chemical examination."

Another very interesting ease was that which took plaee at Bangor in the summer of 1882, and which was reported upon by Dr. F. W. Barry in September of that year. In that case the water-supply was taken from a source exposed to contamination, and was very imperfectly filtered, if filtered at all. A case of typhoid fever occurred at a point from whieh sewage contamination could reach the river, just about the intake of the supply. Two other mild cases succeeded it, and from that time a few dropping cases occurred in the area of the supply. On the evening of the 29th of June the mains and reservoirs were suddenly flushed: this caused a great deal of disturbance, and led to the bursting of a 9-inch main. From that time the disease increased in virulence, and was no doubt due to water being passed directly into the pipes without filtration, to make up for the defieiency caused by the burst main; 548 cases and 42 deaths are recorded in this outbreak out of a population little over 8,000.

Another way in which water acts as a carrier of typhoid poison is through milk; in most cases from milk being adulterated with it, although it may be (doubtfully) from the mere washing of the cans with impure water. Attention was first ealled to this only a few years ago (Islington, 1870; Marylebone Epidemie, 1873), but up to 1881 no less than 3,500 cases of typhoid fever had been traced to this source. There were also 800 cases of scarlet fever, and 500 of diphtheria, traceable to milk; although the actual connection of those diseases with water in those instances is not so clearly made out. These are given in considerable detail by Mr. Ernest Hart in the fourth volume of the Transactions of the Medical Congress of London, 1881. The importance of this part of the question can hardly be over-estimated, when we consider that milk enters so largely into the diet of children, and that children are specially those members of the eommunity who are most suseeptible to typhoid fever. It is essentially a disease of the young, and comparatively rarely attacks people after middle age. Fortunately the precaution of boiling the milk is generally suecessful as a preventive; but the grave risk ineurred by the addition of impure water to milk is such, that the praetice of dilution ought to be repressed as far as possible by the inflietion of very severe penalties. At present the punishment is too often merely nominal.

Cholera.—This disease has its home in Asia, in the delta of the Ganges. In that distriet it is endemic—that is to say, eases occur every year in greater or less number. In other parts of the world (even in other parts of India itself) it is only an oecasional visitor, but no place is safe from its ravages, as it does not seem to be

limited in its spread in any great degree by either climate or geographical position. Its invasion follows the track of human intercourse with infected countries, and it is recognised that the disease may be communicated in more than one way—namely, through air, through drinking-water, through food, through clothing, &c. We are not in possession of sufficient evidence to say which is the most common, but there is enough of evidence to show that water plays a very important part. In the first place, in its own home in India, it has been found that the disease has diminished with the supply of pure water, particularly in Calcutta. In that city the only water for drinking used to be obtained from open tanks, which were much exposed to pollution, and the seafaring population in the Hooghly river drank the river-water, into which not only was sewage thrown, but also the bodies of the dead. Some years ago an improved water-supply was obtained, and this was succeeded by a great diminution of cholera among all classes. In particular the European population have been singularly free from it, whole years passing (1874--79-80) without a single death among them from that disease, a state of things before unknown. In Europe a similar course of events has been observable. In Russia the occurrence of cholera in the dead of winter has been explained by the practice of using melted snow, on which all house slops and excreta are thrown, for drinking and cooking purposes. In Silesia certain towns have never suffered from cholera, the one common condition being that the water-supply is from a distance, and cannot be contaminated. Dantzig and Königsberg used to suffer equally: Dantzig obtained a new and pure water-supply, and ceased to suffer; Königsberg continued with the old supply, and continued to suffer. In Holland, water is obtained from different sources: from the *polders* or reclaimed lands, from wells, from rivers, and collected rain-water. It was observed in the last great epidemic that those who drank the polders water died of cholera at the rate of 17·7 per 1,000, those who used wells at 16·8, those who used river-water 11·9, and those who drank rain-water only 5·3; Amsterdam (which has had a pure supply ever since the time of the first Napoleon) only lost 4 per 1,000. The supply of pure water in Rotterdam and Utrecht brought down the death-rate from cholera immediately, and the disease soon disappeared. In England attention was first specially called to this point by the late Dr. Snow, in the well-known case of the Broad Street pump, the water of which was sought after on account of its sparkling qualities. All those who drank of this pump suffered from cholera, and some of the cases were particularly instructive. For instance, at Hampstead, a northern suburb of London, the only deaths from cholera were those of two ladies; and on investigation it was found that they had the water from Broad Street pump regularly brought to them by carrier from London, because they considered it so pleasant to drink. Dr. Snow proposed to take the handle off the pump as a preventive. It was some time before he could prevail on the vestry to do this, but when done it was effectual. A similar case is recorded in America—that of the Van Brunt Street pump in Brooklyn. Millbank prison, to which reference has already been made, is another case in point; it suffered from invasion of cholera up to the time that the Thames water ceased to be used in 1854; since that time no case of cholera has occurred within the precincts, although the epidemic of 1866 was severely felt in other parts of London. Several towns, which suffered severely in former epidemics, have enjoyed comparative immunity in later ones, such as Hull, Glasgow, Exeter, &c. The soldiers in garrison in the United Kingdom suffered

severely in the earlier epidemics, but in the last (1866) only 13 deaths took place among 70,000 men. This was due in a large measure to improved water-supply. Indeed, we may say now that, with a pure water-supply and a good system of drainage, a town or community may look upon the prospect of an invasion of cholera without any very great dread, for under such circumstances the disease, even if imported into the place, would fail to make good a foothold. On the other hand, persistence in the use of impure water, and indifference on the subject of a proper system of drainage or sewage-disposal, are conditions that simply offer a premium to the spread of the disease.

Ague, commonly known as *Fever and Ague*, is a disease that appears to be most frequently transmitted through the air, but we have evidence that water is capable of conveying it also. This has from very early ages been believed, for we find it mentioned by Hippocrates that drinking marsh-water produced spleen-disease, which is always associated with ague. In India a similar belief has always existed among the natives; even the drinking of river-water containing vegetable matter from marshy districts has appeared to produce ague in places which were otherwise free from any suspicion of marsh-poison. Dr. Smart has pointed out the same thing in the mountainous regions of North America. A very interesting case occurred a few years ago at Tilbury Fort, when the artillery quartered there were supplied with so-called rain-water, collected in underground tanks dug in the marsh. The men suffered severely from ague so long as they used the water, but the disease disappeared on other water being taken into use during the repair of the tanks. When the troops returned to the use of the tank-water, the disease broke out again. I analysed the water, and found it to be very impure : in fact, the water from the marsh had soaked in in large quantities, and been drunk by the men under the belief that they were being supplied with rain-water. Although this is an occurrence not likely to be common in this country, it is important as indicating possible dangers to be guarded against.

Dyspepsia (or indigestion) and *Constipation* are met with as consequences of the use of hard water, and also of water containing a certain amount of iron. Habit, in this as in some other cases, sometimes produces what is called *tolerance* of the conditions, and the system adapts itself in some degree to the circumstances. At the same time, a general improvement in health has been observable in places where a pure soft water has been substituted for a hard one. It is also a known fact that grooms object to give hard water to horses, because it produces a *staring* coat, indicative of impaired digestive functions.

There is some reason to believe that *Sore Throat*, and perhaps even *Erysipelas* and *Diphtheria*, may depend in some cases on impure water. If we bear in mind also that the disease-poison of *Scarlet Fever* and other eruptive diseases is especially present in the particles thrown off from the skin, and if we also remember that such particles (*epithelium* scales) are often found in impure water, we can easily understand that it might be possible that those diseases should be communicated in this way.

Parasites, &c.—In foreign countries, especially in the tropics, there are several dangerous parasites which appear to find their way into the bodies of men and animals through drinking-water. In this country there are but few—viz., one form of tape-worm (by no means the most common), the liver-fluke (probably very

rarely), and the round worms. The case of the last, the round worms, was distinctly proved by the investigations of Dr. Paterson, of Leith, who found that the persons who drank water from a dirty lake in the vicinity (Loch End) were afflicted with those creatures, whilst the families who used the pure supply from the Edinburgh water-works were quite free from them.

Metallic Poisoning.—Metals find their way into drinking-water in various ways, and are apt to produce poisonous symptoms. The metals which have been found in water are iron, manganese, zinc, copper, lead, and arsenic. Of these, the two first are unimportant, iron not being poisonous, although it makes water unpleasant and inconvenient for domestic purposes, and manganese being both tasteless and (so far as we know) harmless. Arsenic is seldom found in water, unless it gets in from the refuse of manufactures, or finds its way in accidentally. Copper may occasionally be found in streams in the neighbourhood of copper mines, but it is more generally got from vessels used in the house. At the same time, it is more frequently associated with food than with drinking-water; so that as regards the latter the matter may be considered unimportant. It is otherwise, however, with the two remaining metals—namely, *zinc* and *lead.*

Zinc.—Attention has only very recently been directed to this substance as a possible source of poisoning in drinking-water. But it is now becoming recognised that some curious cases with anomalous symptoms may be attributable to zinc-poisoning. In large quantities the salts of this metal are emetic; in minute doses they produce a depressing effect on the system. Fortunately, a comparatively small quantity gives a disagreeable metallic taste, although this may be, perhaps, too slight to attract attention, even when the amount of zinc is enough to produce serious effects. The extensive use of so-called galvanised iron utensils is now so common, that this danger must be looked upon as at least possible; for galvanised iron is merely iron covered with a thin coating of zinc, put on by galvanism. Water containing certain substances, such as salts of nitric or nitrous acid (very common in impure waters), or perhaps much organic matter, are very apt to attack zinc and dissolve out a certain quantity. I have found such water, left in contact with zinc-covered vessels for some time, dissolve out so much as to give a strong disagreeable metallic taste. Water, therefore, ought not to be allowed to stand too long in such vessels.

Lead.—This is a much more serious question, both because poisoning by it is more common, and because the effects are much more dangerous. Very small doses of lead are enough, if repeated, to produce poisoning, and some writers mention so little as $\frac{1}{100}$th of a grain per gallon of water. It is doubtful if so small a dose would really have the effect, unless it were prolonged over a considerable time; but it is generally admitted that $\frac{1}{10}$th of a grain per gallon will affect most persons. Professor Wanklyn considers $\frac{1}{10}$th of a grain the limit beyond which he would reject a water. Certainly no water containing so much as that ought to be used, and even with a smaller amount some persons, at least, would be affected. The symptoms of lead-poisoning are colic, palsy, particularly that form known as "wrist-drop," and a blue line along the gums. Lead may get into water from the cisterns or pipes, or from vessels used for holding water. The waters which have most effect upon lead are those that are purest and most aërated, unless there be a large amount of carbonic acid gas; those containing organic, particularly animal

organic, matter; those containing nitrates or nitrites (the result of organic decomposition) and chlorides. But waters containing carbonates, such as chalk waters, and, in a less degree, sulphates and phosphates, have protective influence, for they form a crust on the inner surface of the metal, and so protect it from further corrosion. The best way, however, is to avoid the use of lead as much as possible in any connection with water for drinking purposes. The consumer, however, is not entirely his own master at this point, as the use of leaden service-pipes is generally insisted upon by the water companies; but cisterns need not be lined with lead, and the use of utensils made of alloys containing lead may be avoided.

CHAPTER LXXVII.

COLLECTION, STORAGE, AND DELIVERY OF WATER.

Supply of Rain-water—Tanks—Percolators—Springs, Rivers, and Wells—Area drained by Wells—Pollution of Wells—Land-water—Water-cisterns—Water-pipes.

We must now consider the questions of collection, storage, and delivery of water, in which are included many points of great importance to the health of the consumers. We have already considered the quality of different kinds of water, but we shall have again to speak of some of the sources of impurity, and of the means of preventing them under the above heads.

COLLECTION.

Rain-water.—In some places rain-water forms the only available source of supply, but in this country this is seldom the case, the supply from that source being usually supplemented by some other—usually wells in country districts. Rain-water, however, is sought after on account of its softness, which makes it so much better for cooking and washing purposes. It is quite certain that if more care were taken in its collection, so as to have it free from impurity, and in its storage afterwards, it might form a much more copious and advantageous source of supply than at present. It may be either collected directly from house-roofs and the like, or from fairly pure gathering-grounds, such as sands or uplands away from habitations. In Holland, where the difficulty of getting pure water is considerable, the supply is obtained from gathering-grounds made in the sandy downs, and the result is that a water of great purity and wholesomeness is thus secured, a vast improvement upon the supply which formerly used to be got from the canals and other polluted sources. The most usual way of collecting rain-water in this country is from the roofs of houses or other buildings, and the points to be chiefly considered are these :—1. The quantity and regularity of the supply. 2. The means of preventing its being contaminated before being used or stored for use; or, if it be rendered impure, of removing to some extent the impurities.

1. *Quantity and Regularity of Supply.*—It is necessary to ascertain these points, in order to know how far we can depend upon the supply. We must, therefore, ascertain the area of our collecting-surface, the average rainfall, and the distribution of the rainfall—that is, the amount at different times of the year, and the relation between the driest and wettest years. The average rainfall of the kingdom is given by Mr. Symons at 32 inches per annum, but the range between the extremes is very great. As much as 243 inches have been registered in the Lake district in a wet year, and as little as 14 inches in the East of England in a dry year. Records of rainfall are now kept in so many places, that it is generally possible to get fairly good information on the subject for practical purposes.

The measuring of the collecting-area must next be attended to. In the case of

any flat surface, this is simple enough; but if it be a house-roof or the like, we must bear in mind that it is the area of the *base* of the roof that must be measured, and not the sloping or otherwise irregular surface of the roof itself. The dimensions of the house itself at the ground are not quite enough, as the eaves in general project some distance beyond; therefore, the outline of the roof at the eaves ought to be taken. Suppose we have a small house, say 40 feet by 30 feet at the eaves; this would give an area of 1,200 square feet; multiplying by 144, we should have 172,800 square inches; multiplying again by the rainfall, say 32 inches, we have 5,529,600 cubic inches; this, divided by 1,728, gives 3,200 cubic feet; and this again, multiplied by 6·24, gives 19,968 gallons of water. This somewhat long sum may be shortened considerably, for the same result may be obtained by multiplying the area in square feet by the rainfall in inches, and then by 0·52, thus:—

$$1200 \times 32 \times 0{\cdot}52 = 19{,}968 \text{ gallons;}$$

or, roughly, the area in square feet, multiplied by *half* the rainfall in inches, gives the amount in gallons within an error of four per cent. only,—$1200 \times 16 = 19{,}200$ gallons, a difference of 768 gallons in a year. But the above calculation gives the total theoretical amount, allowing nothing for waste or evaporation. Now every one must know that a great deal is necessarily lost in that way, so that we cannot really expect to save more than one-half, even with the best arrangements. If, therefore, we multiply the area of our roof by *a quarter* of the rainfall, we shall get the probable amount of water obtainable in gallons. In the above example that would be 9,600 gallons.

Let us suppose the house to be occupied by six persons. This would give us 1,600 gallons per head per annum, or a little over four gallons a head daily. This quantity is, of course, quite insufficient as a sole supply, but it would be enough for drinking and cooking purposes, and still leave a small balance to be used in washing. It may here be pointed out that, even if the rain-water obtainable be insufficient for washing purposes by itself, it is still advantageous to mix it with the harder well or spring water, as it will always help to soften the latter.

There are, of course, many dwellings, especially among the cottages of the poor, where the proportion of collecting-area per head is much less than the example taken above; and there are also many places where the rainfall is less than that stated, especially in a dry year, so that the proportionate amount of water obtainable would be small. Still it is always advantageous to have it, if it can be got, for cooking and drinking purposes, if not for anything else. The misfortune is that in too many cases it is not only dirty when collected, but it is stored in butts or cisterns which are neglected, and allowed to become themselves sources of contamination. Of course, where a house-roof is the collecting-area it is certain that a good deal of impurity will always be found, from soot and smoke, dead leaves, droppings of birds, and the like; sometimes in large towns to such an extent as to render the water almost unusable. An ingenious means of removing these to a large extent is Roberts's Percolator (see Fig. 375), the principle of which is to keep out rubbish, and to reject the first rain that falls and washes the roof. This is allowed to run to waste. The apparatus is balanced on a pivot, so that as soon as the pure water compartment is filled to a certain point, it cants over, and the water runs clear to storage. The action is simple and automatic, and apparently not liable to get out of

order. It must, however, be remembered that the action is purely mechanical, and that dissolved impurities are not removed by it.

2. The question of storage of rain-water on a small seale may be eonveniently referred to here. It is usual to keep it either in water-butts or in cisterns or tanks. Butts, if originally elean, and if kept properly covered and protected from impurities, are very convenient, especially for small houses and eottages. A good plan is to have the inside of the butt well eharred with a hot iron. Where tanks or cisterns are used, lead should be carefully avoided, as rain-water is very apt to attack that metal and dissolve small quantities. The best cisterns are of slate, properly put together with hydraulie cement, but not secured, as they generally are, with lead or its compounds. Iron tanks are good if the inside be covered with some lining, such as good cement; but it should not be galvanised, nor should the iron be in direct contaet with the water, as in either case metal is dissolved out, and the water rendered at least unpleasant for use. Brick tanks, if properly cemented inside, answer very well. And there are now many excellent kinds of eonerete and artificial stone of which good tanks or eisterns might be made. In all, however, careful inspection is necessary from time to time, to see that impurities are not aecumulating, as we must bear in mind that "stored rain-water" is placed in the list of *suspicious* waters. When, however, it has been so far filtered clean by means of the percolator, it is much less likely to undergo deterioration when stored.

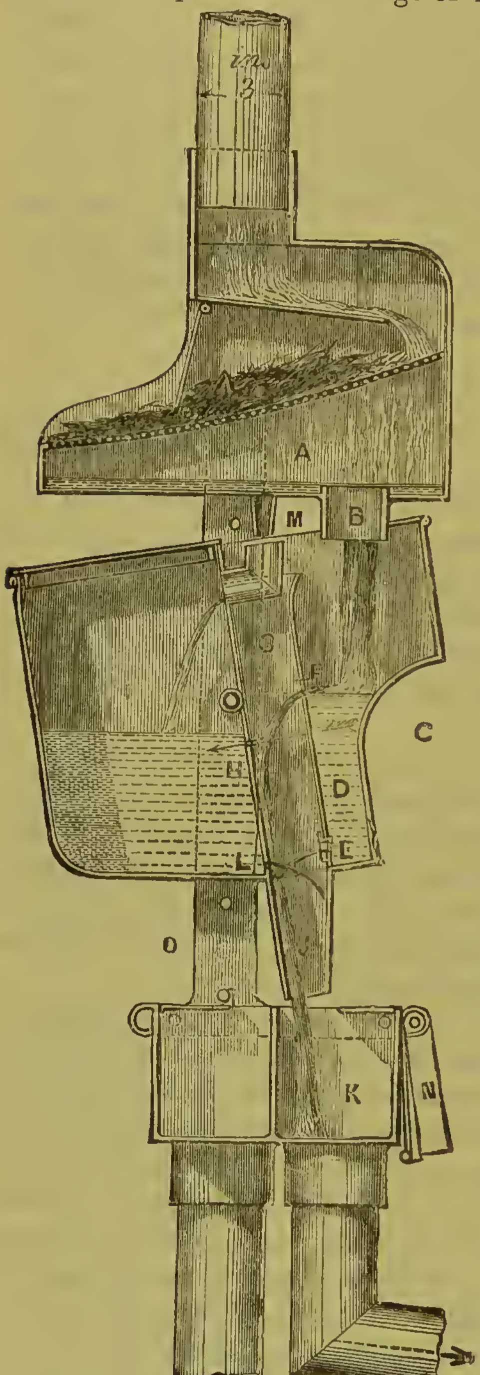

Fig 375.—Section of Roberts's Patent Rain-water Percolator in Action. Pure Water passing to Storage.

The water collected from upland surfaees, or from deep mountain lakes, has much the eharacter of rain-water; it is, indeed, often purer than the rain-water collected directly for domestic use. The water of Loch Katrine, supplied to Glasgow; that of Bala Lake, proposed at one time for the use of the metro-

A. Strainer with perforated plate, to prevent rubbish passing into Pereolator. B. Outlet for water to pass to Percolator C. Pereolator balanced on pivot. D. Small eompartment into which the rain-water first falls. E. Small hole fitted with washer proportioned to size of roof. F. Larger hole to prevent too rapid filling of eompartment D. G. Overflow-pipe for storm. H. Small hole at back of G between compartments. When the rainfall exeeeds the discharging eapacity of hole E, the water rises in eompartment D, and passing through hole H, slowly fills eompartment I. When the weight of the water in I overbalanees the Pereolator, it is canted (as shown in drawing), and the water (by that time pure) direeted by the spout J into the storage-pipe K. L. Small hole at bottom of compartment I. M. Auxiliary pipe for keeping compartment I full after the Pereolator is canted when the rain is leaving off, so that the last drop of rain may be stored. N. Cover for closing over storing-pipe, and for holding the apparatus in its normal position. O. Iron frame to which apparatus is attached provided with holes for fixing to wall.

polis; that of Thirlmere, about to be taken by Manchester—are all very pure waters, containing very little solid matter, an extremely small amount of organic matter, and almost no hardness. Some fears have been expressed that the water of mountain lakes might be dangerous, where there were metalliferous lodes in the neighbourhood, and that thus lead-poisoning might be occasioned. I do not think any evidence has been brought forward to justify this idea; although, of course, before such a supply was taken careful analysis would be made in order to decide so important a question.

Springs are subterranean supplies of water which deliver at certain points of the earth's surface, being either the outflow of a supply at a higher level in some distant part, or being pushed up by the expansion of gas—carbonic acid, nitrogen, or other. In some cases the conditions are such that the water comes up at a temperature approaching to boiling, and in many it is much above the heat of the human body. Those are generally known as mineral springs, and are unfit for domestic purposes, so far, at least, as drinking is concerned. They may, however, be used for baths, and even for washing of clothes, when their hardness is not too excessive. Their chief use, however, is for medicinal purposes, for which many of them are highly important. Fortunately, a great many springs are of a different character, and provide water of a pure, sparkling, cool quality, admirably fitted for all ordinary purposes. Of course, it may sometimes happen that even deep springs may be polluted when access to their source is possible, either through clefts in the ground or pollution of their head-water where it is exposed. Such a condition is, however, not very common. Spring-water (subject, of course, to local variations) generally contains more salts than upland surface-water, but less than deep well-water, the amount of chlorides (represented by common salt) being in the latter usually double what it is in the former. The organic matter is generally very small, and the water is usually well aerated, as might be expected from the circumstances under which it is generally forced up. In collecting it, the points to be attended to are to see that no impurity reaches it at or near the point of collection, and to ascertain that the yield is sufficient either with or without storage. As regards the first point, the water may be fouled by cattle or birds which may have access to it. This may be provided against by simple means; in particular, by providing a convenient trough for the use of animals, and by covering in the delivery-point, so as to make the water flow through a short pipe or conduit. As regards the yield, this is best estimated in small springs by observing how long a vessel of known capacity takes to fill. Any vessel may be used, but a small tub or barrel is the most convenient. A tub 2 feet across and $1\frac{1}{2}$ feet deep holds about 29 gallons; so that if this took one hour to fill it would argue about 700 gallons per diem, a supply sufficient, if all utilised, for about five or six ordinary families. As, however, this means that all the water should be put to use, it would not be nearly sufficient for so many without means of storage, the yield continuing through the twenty-four hours, and not being capable of increase as required. The continuity of supply would also have to be examined—that is, whether or not the yield was influenced, and to what degree, by floods or drought. It is generally safest to take the yield of the driest period as the basis of estimate. Of course, where springs are impounded for an extensive general supply, their waters are conveyed to gathering-grounds or reservoirs, so as, if possible, to utilise the entire quantity.

Rivers.—When a river or rivers are used as supplies on a grand scale, the water is either pumped directly to reservoirs, with or without filtering-beds, or else it is dammed up, so as to form a large reservoir itself. The latter is the plan followed where streams are impounded at their source and where the water can be collected at such a height as to ensure a good head of water; the former when the water is taken from a river in some lower part of its course. There can be no doubt that the head-waters are the best to have, for they partake more nearly of the character of upland surface-waters, whereas at lower points they are exposed to contamination. The public water-supplies of the metropolis, in so far as they come from such streams as the Lea and the Thames, and that of many of our large towns, are more or less polluted. We have allowed sewage and all sorts of offensive matters to pass into our streams, and this polluted water to be drawn for domestic use. Nevertheless, it is plain that our rivers ought to form a good and perennial supply for our population, and the Pollution of Rivers' Act is a step in the right direction, although it will be years before its full effect will be felt. In drawing water from streams, care should be taken to draw it as far from habitations as possible; if possible, above them. Animals ought not to be allowed to water at the same place, certainly not above it. The estimation of the yield of rivers is only interesting to a large community as regards the question of a general water-supply, but the process is simple enough. The mean depth of the river is found by measurement, as also the breadth; the velocity is then obtained by observing the rapidity with which a float passes between two points of known distance; this gives the surface velocity, three-quarters of which gives approximately the mean velocity of the whole stream. Then the mean breadth by mean depth by mean velocity in feet per minute gives the cubic feet of water per minute of flow; this, multiplied by 6·24, gives the amount in gallons. It may also be measured by damming up and forming a weir, the flow over which can be easily estimated by known rules. A table will be found in the engineering division of this section.

Wells are of two kinds, shallow and deep, and the latter may be further divided into ordinary deep wells and artesian wells. Artesian wells, so called from having been first sunk in the province of Artois, in France, are wells of great depth, penetrating a water-bearing stratum which crops up elsewhere at some higher point; by this means the water rises in the well to the height of the outcrop, so as in some cases to flow considerably above the level of the well-opening. Advantage of this is taken in the process of boring, so that the force of the water is sometimes sufficient to force up the *débris* out of the boring-tube. Fig. 373 shows the theory of an artesian well, *a* being the well, and *b* being the outcrop of the water-bearing stratum at a higher level. The plan usually followed is to dig a wide well-hole for some depth, and then to complete it with a long bore-tube of narrower diameter. The water of artesian wells is usually good, but its composition is peculiar, as it contains a larger amount of salt than the best spring-waters, and also often a good deal of ammonia. This, however, has nothing to do with recent organic impurity, and may be disregarded. Its aeration is less perfect than that of other waters, particularly in the absence of oxygen, but it contains enough of carbonic acid to make it moderately palatable, whilst a very short exposure to the air soon enables it to absorb oxygen.

Ordinary wells are, however, of more immediate interest to individuals, as so

much of the water-supply, especially in country districts, is drawn from them. The only way of calculating the yield of water is to find how much pumping is required to depress the water to a given level. As in other cases, the driest year ought to be taken as the basis of calculation. With reference to the selection of the site of the well, and the plan of sinking and securing it, several things have to be considered. Our only chance of reaching water is, of course, to bore into a permeable stratum which has an opportunity of absorbing rainfall, and the water in which is more or less confined by impermeable strata below. For this end, some knowledge of the geology of the place must be obtained. Generally speaking, a well sunk in the neighbourhood of springs will yield an abundance of water; wells also at the foot of hills or at the outfall of a valley will give a good supply. As, however, the situation of dwellings will often be guided by other considerations as well, the choice of place is not always free. The difference, however, between shallow and deep wells is one of great importance, and in many instances it is only a question of expense. Shallow wells are those which are sunk merely into the superficial stratum of porous soil. It is not easy to draw any particular line as to depth, but generally wells less than 30 feet deep must be reckoned in this class, unless there should be an impervious stratum passed through which shall effectually shut out surface-waters. Thus a well 15 or 20 feet deep, passing through a stiff clay before it reaches the water-bearing stratum, is really better than one of twice the depth which penetrates a superficial porous stratum only. Generally speaking, our rule should be to go deep enough to place an impervious stratum between our water-supply and the surface of the ground. If we cannot do this, we must go as deep into our water-bearing stratum as possible, both because the supply will be more plentiful, and because the water itself will have a better chance of being purified by its longer passage through the soil before it reaches the level of the well.

The area of surface drained by wells is a question of some difficulty. It has been stated as a circle, the radius of which is the depth of the well; but this appears to be a grave under-statement of the case, if we look to the evidence which has been obtained from the effects of pumping upon distant wells, or the way in which wells have sometimes been drained by outflows of water at distant lower levels. On these points more details will be given on engineering authority, but one or two remarks may here be made. A well in a gravel and sandy soil in South Hampshire was found to be drained dry in consequence of an outflow of water in a gravel-pit dug a considerable distance off. The difference of level between the higher point (that is, the bottom of the well) and the lower (the outflow at the gravel-pit) was 21½ feet—the distance between the two, 1,720 feet; so that the area drained had a radius equal to 80 times the depth, here represented by the fall or difference in level between the two points. In this case the loss of water was obviated by deepening the well about 10 feet.

Again, the distances at which wells are affected by tides or running waters are also proofs of the extensive areas of drainage. A well on the banks of the Hamble, a tidal river, is distinctly affected by the tides, although the distance is nearly forty times the fall—that is, the difference of level between the bottom of the well and mean tide ordnance datum. The pressure of the Rhine has been known to influence

a well at a distance of 1,670 feet, and at Buda-Pesth, Professor Fodor found the pressure of the Danube influence a well at a distance of 2,700 feet.

These points bear very directly upon the question of the wholesomeness of water; for it is quite clear that if the effect is so marked, wells may drain cesspools, dung-heaps, middens, and all sorts of filthy places; and it really appears wonderful, if this be the case, that well-water should ever be fit for drinking, and that more disease is not caused in this way. It is a fact, however, that fairly good water is sometimes obtained from wells that appear likely to be contaminated. This depends upon three conditions:—1st. The nature of the soil; 2nd. The direction of movement of the ground-water; and 3rd. The amount of water drawn from the well. As regards the first, it is clear that impervious soil, such as stiff clay, will shut off the access of water, and consequently of impurity, from strata beyond it. Thus, a layer of clay will successfully keep out surface impurities, if the well is deep enough to pass through it, and is protected in the upper part. As regards the second point, the direction of the ground-water, it is clear that if a well is dug on the side of any cesspool, &c., towards the direction to which the ground-water is flowing, impurity must be brought into the well. Ground-water always moves towards the nearest running water or towards the sea, therefore it is wise to *weather*, as it were, any source of pollution by placing the well *above* it—that is, on the opposite side to that towards which the ground-water movement may be expected to be. Shallow wells are still further endangered when the ground-water rises after rain, so as to bring the water up to the level of middens and cesspools, which are generally lined with porous material; the water becomes directly contaminated and a source of poison to the consumer. It is obvious, however, that it is possible to prevent some of these dangers by obstructing the entrance into the well of the water from the most impure sources. This is done by imperviously *steining* the upper part of the well—that is, lining the inner surface in such a way as to block out the water that would otherwise flow in from the sides. Thus, a well 50 feet deep, well steined throughout, would draw water only from those parts of the surface at least 50 feet in every direction distant from the well; whilst the water within the area would be compelled to pass through all that depth of soil before reaching that water-level of the well. It is, of course, desirable that wells should be sunk as far as possible from sources of impurity, and the water brought by pipes to the dwelling; but as this is often not done, the best means must be taken to lessen the dangers. Steining is done either with timber, or with bricks, or with iron. Timber is quite unsuited for wells for drinking-water, as it is apt to rot and foul the water. Brick steining is good, providing it is lined with a good coating of hydraulic cement; if not, water will pass easily through, and protective influence will be, to a large extent, lost. A very efficient plan is the use of an iron casing, but the iron must be protected efficiently with cement, or some indestructible non-poisonous paint, otherwise the water will act upon it and wear it through, besides taking up a portion of the iron itself, and becoming unpleasant for use. If we have a well passing through an impervious stratum, such as stiff clay, of some thickness, and imperviously steined down to such stratum, we may generally look upon the water as fairly safe.

The third condition referred to—viz., the quantity of water drawn from a well—is a point to which but little attention has been paid, probably because the wide extent of possible drainage has not been recognised. In the case of a well from

which only a small quantity is taken daily, the water may remain comparatively pure for a considerable time, even under apparently unfavourable circumstances, the water in such a case being probably the surface rainfall soaking through the earth. But if the demand is increased, and still more, if the demand be severe, more and more powerful action will be exercised on all surrounding parts, and water may be drawn from parts of the ground which were previously unaffected by the ordinary moderate demand. In this way porous cesspools, leaking drains, and other sources of impurity, may be tapped, and the water-supply rendered dangerous, so that a well which might suffice for the household originally using it, might yield water unfit for drinking, if too severe demands were made upon it by neighbours less favourably situated.

We have next to look to the question of direct contamination. Wells are either open and used as draw-wells, or closed and the water drawn by means of pumps. The latter are much to be preferred. Draw-wells, if left open, are a source of danger, both because children may fall in and be drowned, and because animals and refuse may get in and foul the water. Wells ought, therefore, to be carefully covered, and the top raised above the soil-level, so as to prevent the inflow of surface-waters during rains and floods. As little wood as possible should be used about them, as it is apt to decay and get into the water. Particular attention ought to be paid to the cleanliness of the bucket, rope, and every part of the gear employed in drawing water. Pumps ought to be of iron throughout, and no lead should be used in any part. The pipe leading from the water to the pump should be either of iron, enamelled, barffed, or otherwise protected; or of solid block-tin: the latter is expensive, but it lasts long, and is perfectly safe. The sink and drain of the pump ought to be of solid material, and so arranged that the water that dribbles away, together with any rinsings of slops, shall run clean away from the well to a proper drain or receptacle.

In some cases Norton's tube-well, called also the American tube-well, or Abyssinian well, is useful, especially where the occupation is temporary. This ingenious apparatus consists of an iron tube in lengths, having at the end a steel nozzle, and the sides perforated to some 18 inches from the end. The tube is driven into the ground by means of an apparatus called a "monkey," successive lengths being screwed on until a depth of 20 feet to 28 feet is reached. A small hand-pump is then screwed on to the top, and, if the stratum be a porous one well supplied with water, as much as 600 gallons an hour may be obtained. This tube-well was used with advantage during the Abyssinian campaign.

Water from Land-drainage.—In view of the difficulty of getting pure water in the country districts, it might be well worth consideration whether or not the water from the subsoil-drainage of land might be utilised.

The objections which might be made to the use of land-drainage water are chiefly those having reference to its possible composition. But the results of a careful examination of the evidence to be found in the sixth report of the Rivers' Pollution Commissioners, and the elaborate papers of Messrs. Lawes, Gilbert, and Warington, lead to the conclusion that the amount of possible impurity is not so large as we might be inclined to expect. It is shown that in almost all soils, except stiff clay and the like, there is a very rapid conversion of organic nitrogenous matter, first into ammonia, and secondly into nitric acid, which forms nitrates with bases,

and is the main source of the nitrogen which crops obtain from the soil. This takes place by the action of some minute organisms, of the nature of ferments, which appear to exist in all loose soils, but perhaps more especially where much sand or gravel is present. If the soil is too porous, the nitrates may flow off with the drainage, and be so far lost for agricultural purposes; but, if the soil be of a proper consistency, they will be retained, and will be readily yielded to suitable crops. It is especially nitrogenous organic matter which we are desirous to keep out of our drinking-water, and, therefore, if we find that there is in the soil anything that will quickly oxidise or burn up such matter, it will be all the better for our water-supply. We know that surface-waters from uncultivated lands, especially uplands, are fairly good, and are put in the list of wholesome waters, although they may be, from want of aeration, not quite as palatable as spring-waters. From such lands the land-drainage water may of course be used with as much confidence as wells sunk in such lands, or, indeed, as the surface-waters themselves. But, when the land is cultivated and highly manured, the case is different, and the use of the land-drainage water may be open to question. Analysis, however, shows that growing crops rapidly absorb nitrogenous matter from the soil, so that but little is found in the drainage-waters. If land is manured without being cropped it may be different, for the nitrogenous matter may find its way out by the drainage. But the conversion of the nitrogenous matter into nitrates (that is, into inorganic matter) takes place chiefly in the upper layer of the soil, or that part where the aeration is most perfect, so that if either the soil be of such a consistency as to retain the organic manure in the upper layer long enough, or if, being more porous, it is also more thoroughly aerated, the conversion may take place tolerably rapidly, and nothing may reach the land-drainage water except in an inorganic, and, therefore, practically innocuous condition. At the same time it is desirable to have a considerable depth through which the water should pass before it reaches the land-drains, so that as much as possible of the organic matter may be removed that may perhaps not have been thoroughly oxidised. The depth of the land-drains should not be less than six feet, but in some cases a greater depth would be desirable. We may, therefore, draw the following conclusions :—

1. Land-drainage water from stiff soils may be contaminated so as to render it unsuitable for drinking-water where manure is used, there being little power of conversion into innocuous substances, and the water being, therefore, liable to run down through fissures, carrying with it a considerable amount of impurity.

2. Where there is a suitable loose soil, of a proper consistence, the drainage-waters may be used, and will in many cases be purer than that from shallow wells. But there are some qualifying considerations, thus :—

(*a.*) Land-drainage water from uncultivated land unmanured, or a *bare fallow*, may in most cases be safely used, if there are no known sources of contamination.

(*b.*) Land-drainage water from lands manured with chemical substances, such as super-phosphates, ammoniacal salts, &c., may be used with impunity.

(*c.*) Land-drainage water from lands manured with ordinary farmyard manure may be used with caution, but is, generally speaking, likely to be innocuous whilst the surface is covered with *growing* crops.

(*d.*) Land-drainage water from lands manured with night soil or town drainage

had better be avoided, although it is probable that even this is purer, if from cropped land, than the water of many wells in surface strata.

It will of course be understood that land-drainage waters are not recommended as sources of supply if better can be obtained; but it seems likely that they may in some cases provide a useful means of obtaining water under certain conditions, and the supply, if selected with care, will generally be purer than the surface village well, which is in many instances in fatal contiguity to the cesspool.

STORAGE AND DELIVERY.

The storage of water is of two kinds—viz., that on a great scale which is inseparable from a system of a general water-supply, and the storage in or near dwellings in small tanks and cisterns. In ancient times, particularly in the hot countries of the East, the collection and storage of water was one of the great solicitudes of enlightened rulers, and we have to this day remains of gigantic works in our own dominions, which have unfortunately been allowed to fall into decay. In Ceylon, for instance, there is still existing a tank, or rather artificial lake, no longer used but in tolerable preservation, which has a circumference of 40 miles. Such a tank, if only six feet deep, would hold an ample supply (25 gallons a head daily) for about twelve millions of people. We have no modern works to compare with this, but the storage required for our great centres of population is still very great. Large tanks, or reservoirs, are built up of earth or masonry, but smaller tanks are made of various materials. The cisterns which are used in houses are made of lead, iron, zinc, slate, &c. Of these lead and zinc ought to be given up, on account of the danger of their yielding metallic poison to the water. Iron cisterns are also undesirable, unless covered inside with some protective material; if that is not done, the iron soon becomes eaten into, and a quantity of rust is deposited. The water becomes red and unpleasant to both sight and taste, besides staining clothes that are washed or rinsed in it. If, however, the inside be lined with cement, of which there are many good kinds, this difficulty is got rid of. The best cisterns, however, are those of slate, provided the slate is put together with some non-metallic cement. It is still, however, frequently the custom to set the sides in lead, a convenient process for the maker, but very dangerous for the consumer. Concrete and artificial stone are now so well made that tanks, baths, and cisterns may be made of them with advantage, as they can be fashioned in one piece without any joint whatsoever.

Cisterns ought to be covered to prevent impurities getting in, but they ought also to be well ventilated, otherwise the water in them is apt to become foul. Where there is any danger from frost, they ought to have sloping sides, so that the bottom is smaller than the top; by this arrangement water freezing has room to expand upwards and outwards without endangering the integrity of the cistern; whereas, if the sides were perpendicular, the lateral expansive force would separate the sides, and as soon as a thaw came the house would be flooded. Cisterns ought to be placed in convenient positions, well lighted, so as to admit of frequent inspection, and they ought to be periodically cleaned, not less often than once a quarter. In all places where water is supplied on the intermittent system—that is, where it is turned on only at certain times of the day—cisterns are necessary, in

order to store sufficient for the day's consumption, or for the interval between the periods, whatever they may be. In all cases, storing water in the house is attended with disadvantage, as it becomes exposed to sources of contamination; but where it is necessary, as above shown, our object must be to make those dangers as few as possible. Some points have been already referred to, but there remain others of the greatest importanee. The *first* is to see that there is a separate cistern for drinking and cooking purposes, having no direct eonnection with any water-closet; *second*, each closet, or set of closets, must be supplied from a special cistern, which should have *no tap* or means of drawing water from it, except by the pulling of the handle for the flushing of the eloset. The best plan is for each closet to have a small service-tank, or water-waste-preventer, which is discharged each time the closet is used, filling afterwards from the special cistern. The objections to the commoner forms of service-box are that the quantity of water is too small, and that the refilling is too slow. It is, of course, the interest of water-companies to prevent too great expenditure of water; but, on the other hand, a free supply is essential for the health of the consumers. Each water-waste-preventer ought to discharge two to three gallons, and to be capable of refilling immediately; this will ensure a good scouring out of the pan and complete washing away of the excreta. Cisterns must be provided with overflow-pipes, in case they become too full; but frequently those pipes have been led into closet-pans, D-traps, or into the drain itself. This ought *never* to be the case. If it be done, foul gases are pretty sure to pass up and eontaminate the water. Cases of diarrhœa and typhoid fever, not to mention other diseases, have been frequently traced to this evil practice. All overflow-pipes should discharge through the wall into the open air, over a grating, covering a trap that leads to the drain; by this means all danger is avoided. Sink and bath wastes ought also to discharge in the same way. Fig. 376 shows the overflow-pipe of a tank or cistern as it ought not to be, and Fig. 377 as it ought to be; (*a*) shows a tank with the overflow-pipe diseharging directly at (*e*) into the drain (*d*); A shows a similar tank, with the overflow-pipe, B, discharging in the open air at C, over a trapped grating leading to the drain, D. It is obvious that in the former case any foul air from the drain has free and direct access to the tank, *a*, whereas in the latter any foul air that might arise would be dissipated into the surrounding atmosphere without affecting the water in A. Instead of the kind of overflow-pipe, B (teehnically called a standing waste), a good plan is to have an overflow or warning pipe simply taken through the nearest outside wall, as shown by the dotted line at E. No water will come out of this pipe unless the ball-coek of the cistern is out of order, and if it is, the

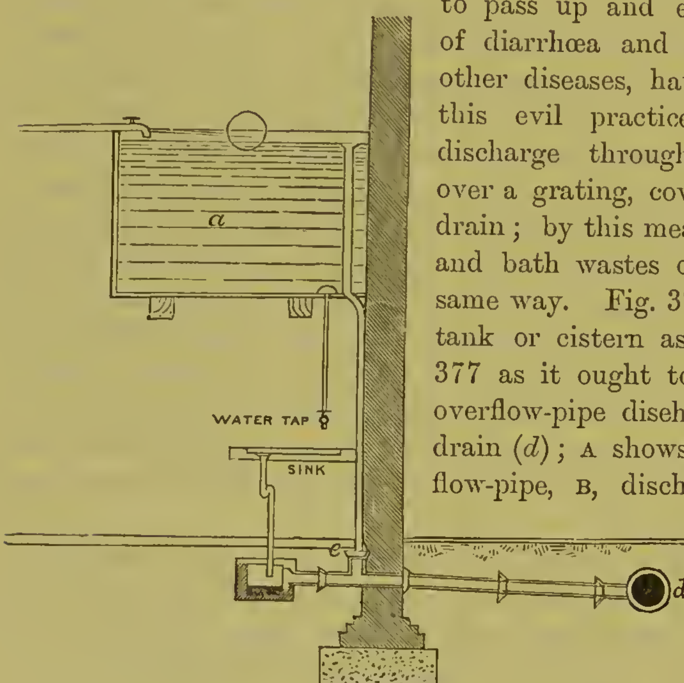

Fig. 376.—Water-waste as it ought not to be.

fact of the water spouting into the open air will call attention to the defect. This arrangement is now generally insisted on by water-companies.

Distribution of Water.—The distribution of water by means of pipes to dwellings is quite a modern arrangement, and in many places it does not yet exist. Not many years ago in Paris, the greatest city in the world after London, water was almost entirely distributed by hand, a supply being obtained in buckets from the water-carrier each morning. The inconvenience, not to say danger, attending such an arrangement is obvious. But even where a general supply is provided through pipes there are various modifications which greatly affect the advantages and convenience of the plans. The plans are mainly two—namely, intermittent distribution with storage in the house, and continuous or constant supply, with the water in the pipes always at high pressure, and with no storage within the house. We have already seen some of the disadvantages of the intermittent system, and to these we may add the want of water, should there be a sudden demand for it (as in case of fire), and the cisterns be emptied before the time for refilling recurs. On the other hand, the continuous system provides water at all times, so that no storage, with its attendant dangers, is required. But there are still points to be looked to connected with it. In the first place, the supply must be really and truly continuous, and not so only in name. In some instances this has not been the case, the supply being intermitted for various reasons. Under those circumstances it has happened that, the suction being inwards, the pipes have drawn in foul gases and liquids in such a way that fœcal matter from closets and blood from slaughter-houses have been found in the water. Outbreaks of fever arising from this cause have been described by Dr. Buchanan at Caius College, Cambridge, and also at Croydon, where the danger was actually foreseen and warned against by Dr. A. Carpenter. Of course the pipes ought not to have been placed in such relations to sources of impurity as to render the occurrence possible; but this does not excuse the imprudence or ignorance, to say the least, which allowed or ordered the intermission. Objections have been made to the constant supply, on the ground of waste, and also on account of the fear that the more expensive fittings necessary would be stolen. In spite of these objections, a large number of towns are already supplied on the constant system, and it is to be hoped that ere long all

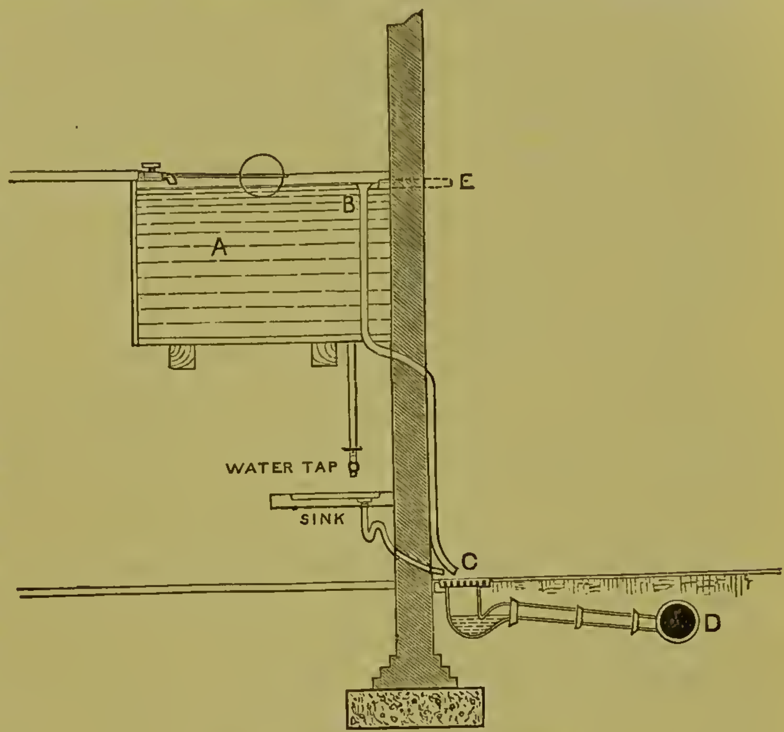

Fig. 377.—Water-waste as it should be.

will be so supplied. In actual practice it has been found that the constant system is really more economical than the intermittent, because the fittings necessary are better in kind and quality, and there is more careful inspection. There is not much danger of fittings being stolen, because, in the first place, that could only be done at the price of flooding the house, and, secondly, because the sale of them could be easily prevented by enactment. As regards waste from not turning off taps, a simple way of preventing that would be to allow no tap to be over a sink, so that the person drawing water would be compelled to turn it off in order not to flood the house. It is important that water should be supplied not only to every house, but to every floor of every house, and this is especially necessary where a building is let out to different families in flats or tenements. With reference to the supply for closets on the constant system, the use of a water-waste-preventer would get rid of any danger of contaminating the water-supply.

Means of Distribution.—The ordinary means of distribution is through pipes of various kinds. In former days, when the population to be supplied was moderate in amount, pipes were often made of wood, hollowed out of trunks of trees. Such pipes are not infrequently turned up in making improvements in or near towns. At the present day, when such enormous quantities of water have to be conveyed, wooden pipes would not bear the pressure, and, accordingly, all the mains are now made of iron. Very strong and good pipes can now be made of concrete, and perhaps it may be found convenient to use it in some instances. At present, however, nearly all the distributing-pipes for water are made of iron, except those actually in the house itself. There are, of course, objections to iron pipes, for the same reasons as those urged against iron tanks, but they can be obviated by having the pipes glazed inside. A bituminous lining is also used, but it is a long time before the tarry taste is got rid of. Perhaps Barff's process—namely, coating iron with its magnetic oxide—may be made available. At the same time it may be stated that iron pipes kept *constantly full* soon cease to yield anything to water, unless the water contains nitrates. Within dwellings leaden pipes are more or less generally employed, and are indeed insisted upon by water-companies for the prevention of waste in case of bursting, a few blows of a hammer being sufficient to close a leaden pipe, whereas an iron pipe would be much more difficult to deal with. Where there is merely a short service-pipe, from which any water that has lain for any time may be drained off before drawing for use, it is of less consequence, but it would be infinitely better to prohibit the use of lead altogether. Iron pipes are cheap, and may be rendered impervious to the effects of water, whilst dangers of loss from bursting may be obviated by having them properly protected from frost, and by having a general cock by which the water could be turned off at once as it enters the house. Various other substitutes for leaden pipes have been proposed, of which we need only notice one or two. Tin (solid block) pipes have been employed, but they are very costly. In some buildings (such as the Royal Victoria Hospital at Netley), the service throughout is of tin, and where a pipe has to draw from a well this is certainly the safest material to use. It has been suggested that leaden pipes, with about 3 per cent. of tin, should be used, it being stated that in such combination lead is not acted upon. I think it would be very unsafe to depend upon any such arrangement, and I believe later experience has shown its fallacy. The only safe combination of lead or tin is the tin-lined leaden pipe, or, as it is called, the

leaden-cased tin pipe, in which the tin is not a mere coating, but of a sufficient thickness to protect the lead satisfactorily. Of course, if the tin were broken through, the danger would be increased, because galvanic action would take place from the presence of the two metals in contact with water, and greater solution would be the consequence. Copper pipes lined with tin have also been suggested, but, like the block-tin pipes, they would be very expensive. For hard waters zinc has been employed, such waters not acting on zinc any more than on lead. If, however, there be nitrates in the water, nothing will protect metal pipes, except glazing, or the use of some non-metallic coating.

CHAPTER LXXVIII.

PURIFICATION.

Filtration—Limits of the Process—Destruction of Bacteria—Substances used for Filtration—Charcoal—Spongy Iron—Carferal—Domestic Filters.

In large quantities water is generally purified by subsidence or by some arrangement of filter-beds. Some water-companies do not take the trouble to filter the water at all, and too many do it imperfectly. In the majority of instances attention is only directed to the turbidity or suspended matter. How imperfectly even this is dealt with may be seen by the reports of the official water-examiners, which are published weekly in the papers. Unless water is obtained from springs or deep wells, it is hardly possible to get it without suspended matter at certain times, such as during or after heavy rains; but provision ought to be made for this, and no company has any right to deliver water except in a clear condition, and perfectly free from sediment. If that is not the condition of the water, either the filtering-beds are inefficient or absent, or the tanks, reservoirs, or pipes are in a dirty state. When a large supply is filtered, the plan is to allow the coarser substances to subside in a tank of deposit, and then to pass the water through beds of sand and gravel, the latter of varying sizes. The London companies employ chiefly beds of three feet in thickness, of which five parts are sand and seven parts gravel. The filtration tanks of the Vartry for the Dublin supply are seven in number, through each of which the water passes. Even this, however, would seem to be sometimes insufficient to prevent the passage of a certain amount of suspended matter. Although a slight influence is exercised by sand for a short time upon dissolved matter, yet the greater part of the action is purely mechanical, and after a time the sand must be washed. This is done by means of a machine for the purpose. The use of other substances besides sand and gravel has been suggested, and in some instances actually put in practice—charcoal, both animal and vegetable, magnetic iron oxide or carbide, spongy iron, carferal, &c.—the object being to arrest dissolved as well as suspended impurity. It is, of course, best to have a supply from a source pure enough to do without filtration, although in most cases some mechanical filtration would be required. But where there is any chance of dissolved impurity, it would certainly be well to employ some means of getting rid of it. It may be well to state that there is no means of getting rid of dissolved mineral substances in excess, except carbonate of lime by the chalk process. Sand arrests hardness and common salt to a slight extent, but only for a short time, and the same may be said of all other substances that have been tried. It is, therefore, the organic impurity that can alone be dealt with. Animal or other charcoal has not been tried on a large scale, and would probably not answer in the long run; the chief reason of its not having been used has been the very great expense, animal charcoal (the vegetable is comparatively powerless) costing about £20 sterling a ton. But magnetic iron (Spencer's) has been in use at Wakefield for a number of years, and is said to have answered the purpose. Bischof's spongy iron is now being applied to the same purpose at the water-works of Antwerp, and carferal is likely

to be used in a similar way. All those substances have considerable power in arresting organic impurity in solution. Their use would probably prevent such sad results as those which followed the contamination of the water at Caterham and Redhill, where so large a number of cases and many deaths occurred from typhoid fever, arising from pollution apparently almost infinitesimal in quantity.

In dealing with water on a small scale, there are various ways of treating it, so as to render it fit for use, should there be reason to fear its contamination. They may be divided into two classes, viz:—1. Purification without filtration; and 2. Purification with filtration.

1. *Purification without Filtration.*—The most certain method of all is distilling the water, and next to that boiling only. Distillation is an absolute protection, as nothing comes over in the process but water and such volatile matters as are capable of being volatilised at the temperature of boiling water. These latter are, of course, non-organised, and, therefore, incapable of communicating specific disease. But even if they were so, the heat to which they would be exposed would be sufficient to destroy all energy. The main objection to distilled water is its vapid, flat taste, but this can be got over by free exposure to the air, as is done on board ship by Normandy's apparatus. By this means ships at sea can be supplied with an unlimited amount of fresh water so long as fuel is to be had. In times of war or epidemic this would also be an invaluable plan of obtaining perfectly wholesome water.

Boiling is the next best method, although it does not necessarily yield so pure a substance as distillation. It gets rid, however, of most of the carbonate of lime hardness, and it effectually destroys the energy of all organised poisons—that is, disease-poisons capable of causing such diseases as typhoid fever, cholera, or others. This view has been doubted, on account of the observed fact that minute organisms (known as *Bacteria*) can resist a temperature much above that of boiling water. Tyndall has, however, shown that successive heatings, even at a lower temperature, will effectually dispose of the successive crops of bacteria as they come to the fructifying stage. It may be further pointed out that it is not only not certain that those organisms are connected with the propagation of disease, but apparently pretty well made out that they are at least themselves in no way the actual disease-germs. We may, therefore, rest well assured that no disease-poison, however virulent, will resist the temperature of boiling water, and that water so treated may be taken without fear of bad result, even though it may have been previously seriously contaminated.

Exposure to the air is another means of purification, but it is more efficient if the exposure takes place in finely-divided currents. At the same time, the plan is uncertain, and would be difficult of application for household or private purposes, particularly as the action is somewhat slow.

The Addition of Substances to the Water.—If water is turbid, especially with fine silt, which sometimes quite eludes sand-filters, the addition of a little alum will clear the water, if it be well stirred up and then allowed to stand quiet for a little. The quantity used must be small, about six grains per gallon, or else we increase the hardness of the water and add an unwholesome ingredient.

Infusion with tea and other astringent vegetables is also good in emergencies, and generally renders organic matter harmless. Cases have been observed where

typhoid fever has been apparently spread by drinking-water; but the disease was confined to those who drank it in its ordinary condition, whereas those who took it in the form of tea escaped. In such a case protection is doubly afforded by the water having been boiled, and also by the action of the tannin as a coagulating and precipitating agent.

2. *Purification with Filtration.*—The use of filtration on a large scale has already been referred to, and we have now to consider the means which are applicable to domestic purposes. A great many filters are in the market, and, of course, each maker thinks his own the best, and has it puffed accordingly. It is not, however, always the one that is most praised that is really the best, and in the matter of filters, many of the older kinds were not only useless as water-purifiers, but positively injurious to the quality of the water, and a source of danger to the consumer. Such were the filters containing only a small quantity of filtering-material, which was carefully cemented up, so that it could not be got at for the purposes of cleaning or renewal. It is essential to bear in mind that all filtering-material is limited in its power, both as to bulk and as to time. A small quantity in proportion to a large bulk of water will become soon fouled; a larger quantity used for too long a time will have a similar result. It has been too often the notion that all that needs to be done is to get a filter and go on using it for an unlimited time without any other precaution. But in course of time the filtering-substance will become so highly charged with impurity that, instead of removing organic matter from the water, it will yield what it contains to the water. In this way water may be rendered by filtration a great deal worse than before, and accidents have occurred, such as attacks of diarrhœa, from the use of water drawn from dirty filters. The substances employed for filtrative purposes are numerous.

(*a*) *Mechanical Substances.*—Sand, which we have already referred to, fine gravel, porous stone, ground pumice-stone, finely-ground slag (*scorie de fonte*), &c. Any one of these is good for arresting suspended matter, and the more angular the fragments are, apparently, the more efficacious they are. In cases of river-water with very fine silt they are apt to choke. They have, however, very little action on dissolved matters, either mineral or organic. In some cases they have been used in combination with currents of air under more or less pressure, and it is said that this is capable of destroying organic matter in solution. It is on this principle that the *Chanoit* filter, used in France, is made, the substance used being the *scorie de fonte*, or ground slag. The water is driven into the filter, which is a strong iron vessel, through a layer of the filtering-substance; the pressure compresses the cushion of air at the upper part, so that when the tap is opened the water flows out highly charged with air, and sparkles like soda-water. In order to wash the filtering-material, a tap at the lowest point of the filter may be opened, when the compressed air will at once drive the filtered water back through the filtering-material, carrying with it the impurity that may have accumulated. The action of this filter has been much approved of in France, but I am not aware of any conclusive experiments that have been made to ascertain its real power by chemical analysis of the water.

Another mechanical method is the form employed in the *Maignen* filter. This has been employed on both a large and a small scale. The principle consists in exposing a very extensive relative filtering-surface to the water. This is done by stretching asbestos cloth over wooden frames placed close to each other. All the

water is thus compelled to pass through a relatively large filtering-surface. The filtering-power may also be increased by covering the cloth with some of the filtering-powders or granules, such as charcoal, or the like. When the Clark process for softening water is used, the carbonate of lime deposited forms a natural filtering-medium, which assists the process. The Maignen filter is very rapid, and the filtering-cloths may be frequently and easily changed and cleaned. Acting alone, however, it is at least doubtful if dissolved substances would be much affected by it.

In a good many filters sponges are used to stop the suspended matter and prevent the filter being clogged, but this is not a good plan. The sponge is apt to get soon foul, and requires constant attention and frequent cleaning and renewal. A plug of asbestos is the best substance, as this may be purified by being heated to redness.

(b) *Substances supposed to act Chemically as well as Mechanically.*—Of these the best known and most frequently used up to the present time are the various forms of charcoal. Common wood charcoal has been tried, but experiment has shown that its power is very limited, as it has but little influence over dissolved organic matter, and very slight power of removing colour from water. Peat charcoal and sea-weed charcoal appear to be more useful in those respects. None of them, however, are at all equal to animal charcoal, a substance prepared by calcining bones, crushed to fragments, in closed vessels, air being carefully excluded. The resulting substance is black and granular, and consists of ten to twelve per cent. of carbon and the remainder of mineral matter, chiefly phosphate of lime. There is also a good deal of nitrogen contained in the pores of the substance. Animal charcoal has very considerable power in removing dissolved organic matter and colouring-matter from solutions. This it appears to do both by its porosity and also by the fact that it is capable of absorbing and retaining oxygen to a very great extent, in fact to the extent, it has been stated, of one thousand times its own bulk. Analysis has shown that the organic matter is actually acted upon by this oxygen, and converted into harmless products. If this were all, nothing better than animal charcoal need be required for filtration, and, indeed, it still forms a valuable substance if it be used with care and judgment. But it has disadvantages of a serious character. If water filtered through it be stored for any length of time, it is apt to undergo change for the worse. Organisms begin to develop—minute moving bodies and low forms of plants—which render the water offensive. It is also observed that water left long in contact with the charcoal is apt to take back impurities from it, and ultimately to become worse than before. It is, therefore, clear that the oxidation of the organic matter is not complete, and that either minute germs may pass through the charcoal, or that it yields to the water substances which favour the propagation of germs absorbed from the atmosphere. Probably both conditions are at work, the substances yielded being phosphates and nitrogen. Another point of great importance, bearing upon this part of the question, is that fresh, and we may say vital, organic matter is only partially arrested by charcoal, fresh white of egg, for instance, passing through with considerable ease. Charcoal is used either in minute fragments or made into solid blocks. Both act well, with the above limitations; but the looser form appears to be much the better of the two, as the blocks are apt to clog, and require a good deal

of looking after and cleaning. Attempts have been made to remove some of the objectionable substances from animal charcoal by treating it with acids, so as to dissolve out the lime phosphate, but this has only partially succeeded.

To clean charcoal, the best plan is to take it out and re-heat it to low redness; or, if this is not convenient, it ought to be boiled with about half a pint of Condy's red fluid, and a tea-spoonful of oil of vitriol to a gallon of water. After that, the

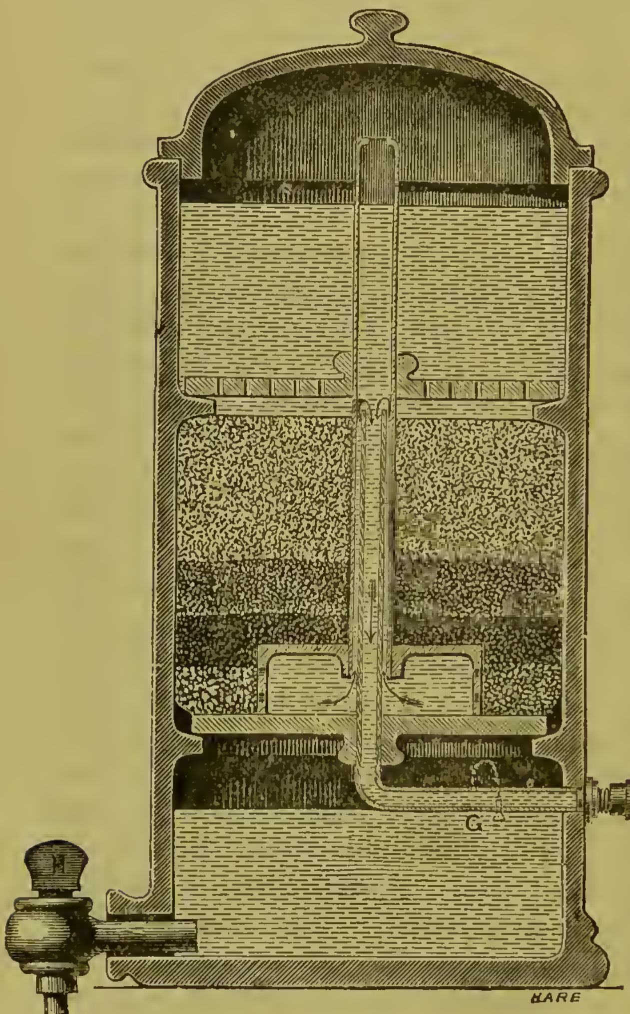

Fig. 378.

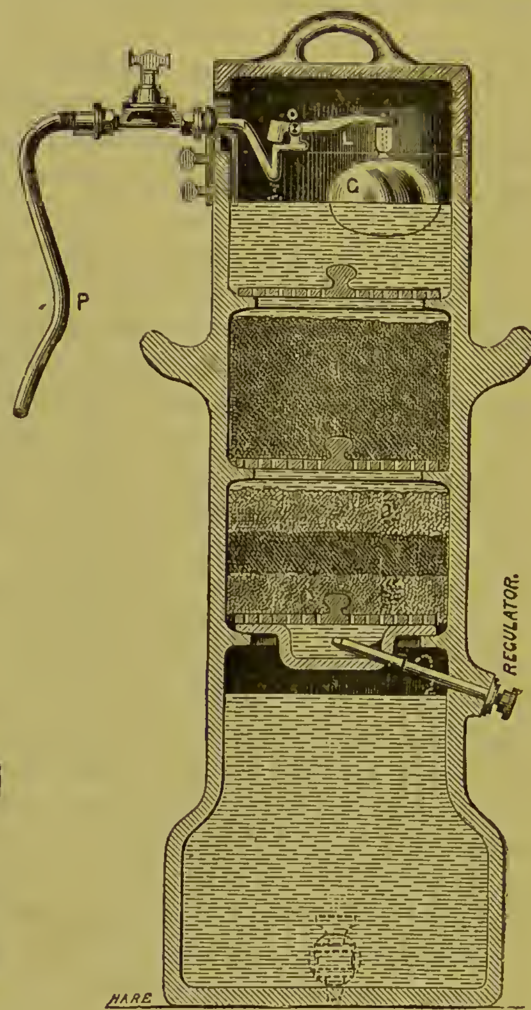

Fig. 379.

water may be strained off, some clear distilled water poured through, and then the charcoal spread out and dried in the sun. If the filter is a closed one, the substances above mentioned may be passed through it the reverse way—that is, pouring them in at the tap to come out at the top, finishing up with a gallon or two of distilled water.

Having regard to the objections to animal charcoal, other substances have been proposed, such as spongy iron, magnetic carbide, carbonised ironstone earth, carferal, &c. Probably many substances will be found of use in the course of future inquiries. At present I shall confine my remarks to two only—namely, spongy iron and carferal, as I have personally investigated them. Spongy iron is obtained from iron ore by calcination. It is a granular substance, very porous, and much

resembling animal charcoal in appearance. It takes oxygen from water, and by its means organic matter is oxidised and destroyed. It is apt, however, to yield a little iron to water, but this can be got rid of by passing the water afterwards through *prepared sand*, a mixture consisting of fine gravel and pyrolusite, which is a crude oxide of manganese. For complete action, water requires longer exposure to spongy iron than to animal charcoal, but with a filter of sufficient size this delay is unimportant, at least for domestic purposes. Spongy iron yields nothing to the water which tends to make it become bad, and it may, therefore, be stored or left in contact with the filtering-material with impunity. Fig. 378 shows one of the forms of filter convenient for domestic use. Fig. 379 shows another adapted for connection with a supply-pipe P, the filling being controlled by means of a ball-cock O, L, G. The principle of the two is identical, the upper part containing the spongy iron, the next compartment the prepared sand, and the lowest the cistern or receptacle for filtered water. There is an arrangement for keeping the water at a certain level, so as to cover the spongy iron, for unless this is done it is apt to cake and harden, and require removal. The rate of filtration is controlled by means of the small tube (of junction) G, in which a minute hole is drilled. The average time of exposure of the water to the filtering-medium is about 22 minutes. The materials do not require to be renewed more frequently than once a year, even in the case of rather impure waters.

Carferal is a substance the details of the manufacture of which have not yet been made public, but its basis is alumina (clay), with a little iron and carbon. It is a fine black granular substance, and has a powerful influence in removing organic matter, and in decolorising solutions. It yields nothing to the water, which may be stored after filtration without danger of deterioration. It has been used in the filters designed for the public service by Lieut.-Colonel Crease, C.B., Royal Marine Artillery. Fig. 380 shows a section of a filter which is cylindrical in form, but larger filter-tanks are made square or oblong. There is no reservoir required, but merely a perforated plate at the bottom. Upon this the filtering-medium (C) is placed, and this covered with another plate, which is screwed down to any required degree of compression by means of the handscrew (F) working on the upright rod.

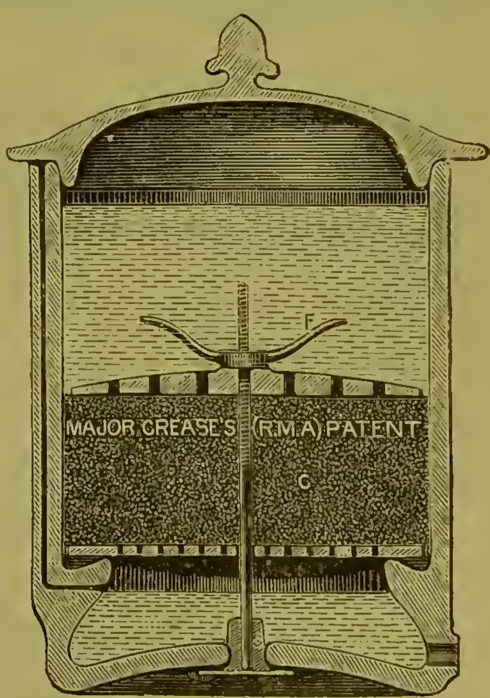

Fig. 380.—Carferal Filter.

The greater the compression, the more closely packed is the carferal, and the longer the water in going through. Fig. 381 shows the filter adapted in connection with a water-supply. The simplicity of these filters is an advantage, and the material can be easily got at for purposes of cleansing or removal. Carferal may be exposed to a low red heat, or boiled in distilled water, and so rendered fit for use again. With ordinary waters, once a year would be sufficient for renewal.

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The Maignen filter may be converted into a chemical one, particularly in the domestic form, or "Bijou" filter, by using any of the filtering-materials mentioned. The filtering effect will, of course, depend upon the amount of the medium used; the form of the filter, and the ease with which the filtering-material can be renewed, are advantages attending its use.

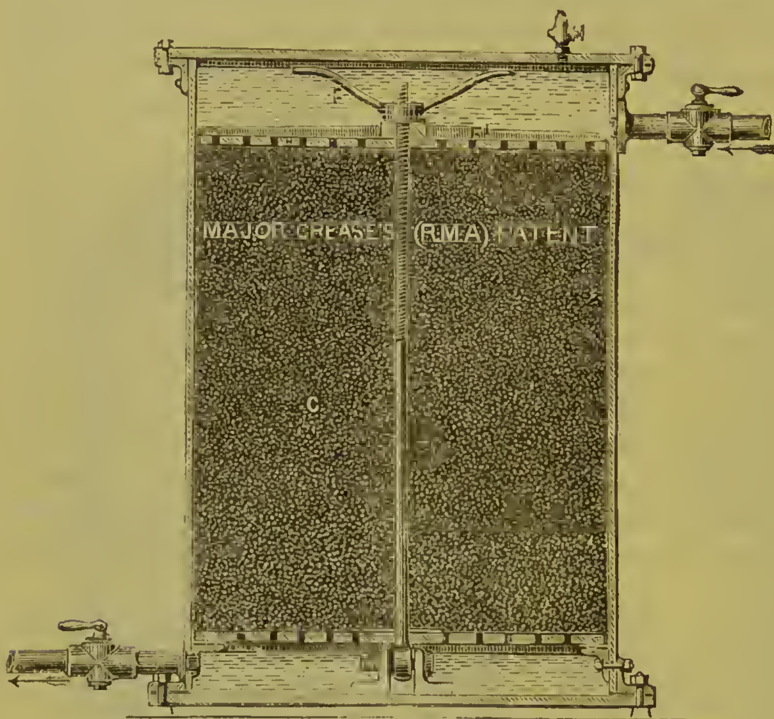

Fig. 381.

There are, of course, other filters which are efficient, but it is a good rule to lay down to have nothing to do with any filter where the material is sealed up so that it cannot be got at without taking the filter to pieces. It is also necessary to bear strictly in mind that the best filter is limited as to power, and especially as to time. Every filter ought to be carefully inspected, and, at periodical times, the material ought to be removed and thoroughly cleansed, if that be possible; and if it cannot be cleansed, a fresh supply ought to be substituted for it. The small expense incurred in this way is a wise outlay, in order to secure immunity from dangers that are otherwise certain to arise sooner or later.

CHAPTER LXXIX.*

RAINFALL AND PERCOLATION.

Water-bearing Strata—Rain-gauge—Amount of Rainfall—Percolation-gauge—Amount of Percolation—Relation between Rainfall and Percolation—Conditions which influence Percolation.

The health and comfort of a community is so entirely dependent upon a supply of pure water that, as Prof. Prestwich, F.R.S., has well pointed out: "The site of a spring or the presence of a stream determined probably the first settlements of savage man, and his civilised descendants have continued until the last few years equally dependent upon like conditions—conditions connected, firstly, with the rainfall, and, secondly, with the distribution of the permeable and impermeable strata forming the surface of the country."

London is a striking instance of this. It stands on a bed of gravel varying in thickness from ten to twenty feet, overlying strata of impermeable clay. This bed of gravel formed an easily-accessible underground reservoir, feeding innumerable shallow wells, and also giving rise to a number of springs, such as those of Bagnigge Wells, Holywell, Clerkenwell, St. Chad's Well, and others. The early growth of London followed unerringly the direction of this bed of water-bearing gravel through Whitechapel to Bow, through Hackney to Clapton and Stoke Newington, and through Kensington to Chelsea; while it came to a sudden termination for many years at Clerkenwell, Bloomsbury, Paddington, and Bayswater, where the bed of gravel abruptly terminates, and the London clay comes to the surface. Here and there in the midst of the London clay there were a few outliers of gravel, such as those at Islington and Highbury, and on these outliers habitations followed. In the same way, on the outskirts of London, a succession of towns and villages grew up, following for miles the great beds of water-bearing gravel, whereas, with the exception of Kilburn, hardly a house was to be met with forty years ago between Paddington and Edgeware, where the London clay cropped up to the surface.

The introduction of a public water-supply rendered wells no longer necessary for each house, and thus removed the barrier which prevented the extension of dwellings beyond the gravel. Then, and not till then, London began to grow in the clay districts.

In the following chapters it is not intended to deal further with the question of town water-supply, but only to consider the water-supply to country houses and homesteads. In the great majority of these the occupants are dependent either upon wells or springs, which derive their supply from the water stored in the various permeable strata; and we therefore propose to consider somewhat carefully the conditions affecting the distribution of underground water.

It seems almost a truism to state that all sources of water-supply are derived from rain which falls on the surface of the ground; yet scientific men formerly held

* This and the following chapters are contributed by Rogers Field, B.A., M. Inst. C.E., V.P.M.S., and J. Wallace Peggs, Assoc. M. Inst. C.E., F.M.S.

a different opinion, and even now many people do not sufficiently realise this fundamental principle. It is self-evident that rivers and surface-streams come from rain; but with reference to underground water the matter is not quite so clear, and a curious opinion formerly prevailed very generally, that springs and underground sources came from the sea. It was supposed that the sea penetrated into the strata forming its bed, and through them was conveyed to a great distance under the land, being so thoroughly filtered in its passage that it lost its saltness. It was also supposed that a portion of the sea-water descended to great depths, where the central heat of the earth acted on it and converted it into vapour, when it rose upwards through the fissures of the rocks, became condensed again as it approached the surface, and finally issued in the form of springs. It is, of course, now known that all this is entirely erroneous; but an indefinite notion still sometimes exists that deep springs come from some mysterious source, such as the "Mother Spring" referred to by well-borers.

No doubt the sources of deep springs are often in one sense mysterious, viz., that the water which feeds them percolates from great distances, and that it is often very difficult, if not impossible, to point out the precise locality where the rain which supplies this water passes into the ground. At the same time the fact is well established that the supply is due to rain falling on the surface of the ground somewhere, and is limited by the amount of this rain, so that any expectation as to the amount of water which can be obtained from deep boring, without taking this circumstance into account, will very likely result in disappointment.

RAINFALL.

As all sources of water-supply are derived from rainfall, it is important to consider this subject before proceeding to the various sources of supply themselves. The amount of rainfall varies enormously in different parts of the world. In England, for instance, the average rainfall is only 30 inches during the entire year; whereas at Cherrapongee, in India, more than this amount has been known to fall in a single day, the average fall for the entire year being 493 inches. On the other hand, there are some portions of the world where rain never falls.

It will be useful, in the first place, to explain briefly how rainfall is measured. The apparatus employed for this purpose is called a rain-gauge, and it has been ascertained that it does not matter much what the size of the gauge is as long as it is not less than 3 inches in diameter. The usual size of gauge used for rain-collection is either 5 inches or 8 inches diameter, and the amount of rain is always recorded as depth in inches and decimals.

The most generally useful kind of rain-gauge is that shown in Fig. 382. It consists of a deep cylinder, *a a*, surmounted by a brass rim, *b b*, which is truly-turned to ensure it being a perfect circle and of proper area. The cylindrical part from *a* to *c* is about five inches deep, and is made for catching snow. At *c* the funnel-shaped part is provided for conducting the water into the bottle at *d*. This bottle is so placed as to be out of the influence of frost and evaporation. The water collected in the bottle is poured out into the measuring glass *e*. The area of this glass bears a known proportion to the area of the rain-gauge, and the graduations of the glass are arranged so as to give the depth of rain which has fallen on the gauge. Usually

each graduation of the glass represents one-hundredth of an inch of rainfall on the gauge. Should the collecting-bottle (d) at any time become full owing to a great fall of rain, it will overflow into the lower part of the cylinder a a, and the rain thus collected can be properly measured. Many valuable records of rainfall have been lost from the receiving-bottle being too small and no provision being made to catch the overflow.

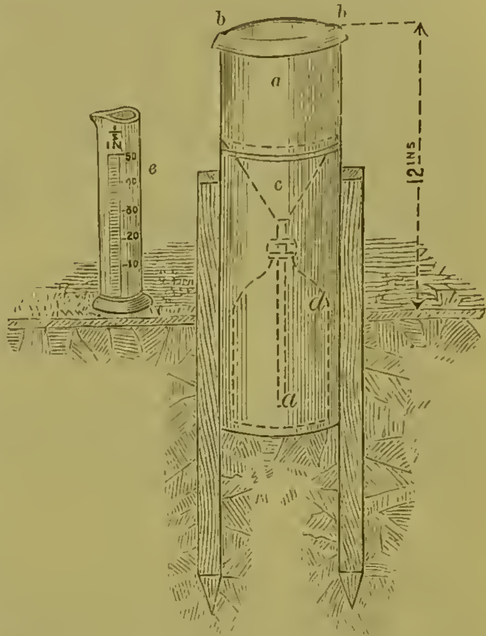

Fig. 382.—Rain-gauge.

The distribution of rain over the British Isles varies considerably, as shown by the complete records of rainfall we now possess in this country owing to the indefatigable exertions of Mr. G. J. Symons, F.R.S. The eastern part of England—that is to say, east of a line from Newcastle to a point in the Thames valley near Reading—has an average rainfall of less than 25 inches per annum. The portion west of this line, and also along the south coast, has a greater average rainfall, varying from 30 to 40 inches per annum, with districts such as the Cumberland and Welsh Mountains and Dartmoor having amounts above 75 inches per annum, and reaching in one case to nearly 200 inches per annum.

The amount of rainfall not only varies in different districts, but also with the season of the year. It has been often stated that the amount of rain falling in winter is on an average greater than the amount in summer; but upon a careful examination of the rainfall records it will be found that this statement is not strictly accurate. We find that in England the districts having a low average rainfall—that is to say, from 20 to 25 inches—have the greater part of the rain falling in the summer months; and districts having an average rainfall of from 25 to 30 inches have an equal amount of rain summer and winter. Districts with an average rainfall above 30 inches have the most rain in the winter. In Scotland, in districts of low as well as of heavy rainfall, the winter rainfall is greater than the summer rainfall.

The amount of rainfall in a mountainous district is usually greater than in a flat district, and it may be stated as a general rule that, within certain limits, the greater the elevation of the land the greater the rainfall. From this we might expect that a rain-gauge placed on the roof of a house or the top of a tower would collect more rain than a gauge placed on the ground, but precisely the contrary has been found to be the case. Dr. Heberden, F.R.S., placed a rain-gauge on the top of one of the towers of Westminster Abbey, more than one hundred years ago, and found that the amount of rain collected on the top of the tower was very little more than half that collected on the ground. Observations which were made on a rain-gauge placed on the top of York Minster by Prof. Phillips, F.R.S., in 1832-35, gave similar results; and since that time numerous observations have been made with rain-gauges on high buildings and isolated poles, all of which show that the rain collected decreases with the elevation above the ground. This apparently para-

doxical result has greatly puzzled meteorologists, and all sorts of ingenious explanations have been suggested. It has, however, recently been proved that there is really no decrease of rainfall at all, but that the apparent diminution is due to the fact that a gauge placed in an exposed position above the ground does not collect all the rain that falls, a certain proportion being blown over the gauge by the wind.

For purposes of water-supply it is not sufficient to know the average rainfall, but we must know the extremes, namely, the rainfall of the wettest and driest years. From an examination of a great number of records of different places, it appears that the rainfall of the wettest year is generally rather more than double that of the driest year. If we assume the rainfall of the wettest year to be exactly double that of the driest we obtain the following approximate rule, which is exceedingly useful in practice.

The fall in the driest year will be one-third less than the mean fall.
" " wettest " " more " "

For example, with an average rainfall of 24 inches, the rainfall in the driest year will be 16 inches, and for the wettest year 32 inches, making the wettest year just double the driest year.

PERCOLATION.

The water which falls from the clouds in the form of rain and snow is disposed of in three different ways. A certain portion runs off the surface, and finds its way directly into the streams and rivers; another portion is taken up by vegetation, or lost by evaporation; and a third portion sinks into the earth, and forms the underground sheets of water which feed the springs that are met with in nearly every part of the world. It is stated that one-third of the rainfall flows off the surface, one-third is taken up by vegetation or evaporated, and the remaining third sinks into the earth; but this can hardly be called even an approximation to the truth, as the proportions differ enormously in different cases, and at different seasons of the year. In a hilly and mountainous country much more water will evidently flow off the surface, and much less be evaporated, than in a flat country. In a district consisting chiefly of retentive clay, hardly any of the rainfall will sink into the ground, whereas in a district composed of permeable gravel or sand a very large proportion of the rainfall may be absorbed by the subsoil. In tropical climates evaporation will be much greater than in cold climates, and even in the same country evaporation will be much greater in summer than in winter.

Extensive observations have been made in different parts of England on the proportion of the rainfall which flows off the surface and can be collected and stored in reservoirs for the supply of towns; and very interesting results have been obtained. As, however, this mode of supply is seldom adopted for single houses, we do not propose to go into the question of the flow off the surface; but will confine our attention to the water which sinks into the ground, and feeds the springs and wells from which most country houses derive their supply.

To determine the proportion of the rainfall which percolates into the subsoil is a much more difficult matter than to determine the proportion which flows off the surface of the ground. In the case of surface-flow, the precise extent of the watershed or area from which a stream derives its supply can be easily ascertained from

an examination of the ground, and then by recording the amount of rain that falls on this watershed, and measuring all the water that flows down the stream, the proportion of the rainfall that runs off the land can be ascertained with considerable accuracy. In the case of percolation, on the other hand, this method is seldom applicable. The area from which a spring derives its supply cannot (except in rare instances) be ascertained from a mere examination of the ground, and frequently cannot be ascertained at all with any certainty. The amount of percolation has therefore generally been determined, not by the measurement of actual springs, but by observations on artificial gauges. The apparatus used is that known as the Dalton gauge, from the celebrated Dr. Dalton, of Manchester, who first employed it. The gauge consists of a watertight vessel, open at the top, and filled with the soil to be experimented on. This vessel is placed in the open air, and is so arranged that the rain which falls on it percolates through the soil in the vessel, and is collected in a receptacle at the bottom, so that the amount which percolates can be regularly measured. In the original gauge used by Dr. Dalton there was an overflow-pipe provided, to take the water that flowed off the surface without percolating, and this surface-water was collected in a separate bottle, and the two quantities added together, so that the total represented the quantity derived from both sources—surface overflow as well as percolation. The gauges constructed since Dr. Dalton's time generally have no overflow-pipe, but are so arranged that the whole of the water has to percolate through the soil. An ordinary rain-gauge is set up by the side of the Dalton gauge, so as to compare the percolation with the rainfall.

The following Table gives an abstract of some of the results that have been obtained by different observers in different localities. It will be noticed that the year is not divided in the usual way, but made to commence with October and end with September, the first six months (October to March) being called winter, and the second six months (April to September) being called summer. The reason for this peculiar arrangement is that it has been found that by far the greater portion of the percolation takes place in the six winter months October to March, and very little in the summer. The division, therefore, which has been adopted gives a better insight into the question of percolation than the usual division.

TABLE I.

		Dalton.	Evans.	Lawes & Gilbert.	Greaves.	Dickinson.	Evans.	Greaves.
		Soil.	Soil.	Rather Heavy Loam.	Soil.	Gravel, Sand and Soil.	Chalk.	Sand.
		3 Years.	7 Years.	5 Years.	14 Years.	18 Years.	7 Years.	14 Years.
		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Winter. October to March.	Rain	14·2	11·9	13·4	13·6	13·8	11·9	13·6
	Percolation . . .	*5·8*	*4·6*	*7·7*	*7·2*	*8·6*	*6·9*	*12·4*
	Difference or Loss . .	8·4	7·3	5·7	6·4	5·2	5·0	1.2
Summer. April to September.	Rain	19·4	14·6	14·5	12·1	12·8	14·6	12·1
	Percolation . . .	*2·6*	*1·2*	*2·6*	*2·5*	*0·5*	*3·0*	*9·1*
	Difference or Loss . .	16·8	13·4	11·9	9·6	12·3	11·6	3·0
Entire Year.	Rain	33·6	26·5	27·9	25·7	26·6	26·5	25·7
	Percolation . . .	*8·4*	*5·8*	*10·3*	*9·7*	*9·1*	*9·9*	*21·5*
	Difference or Loss . .	25·2	20·7	17·6	16·0	17·5	16·6	4·2

Dr. Dalton's observations were carried out at Manchester in the years 1796-97-98. Mr. Evans' observations were carried out at Nash Mills, near Hemel Hempstead, Hertfordshire, in the years 1853 to 1860. Messrs. Lawes and Gilbert's observations were made at Rothampstead, Hertfordshire, in the years 1870-1875. Mr. Greaves' observations were carried out at Lea Bridge, Essex, in the years 1860-1873. Mr. Dickinson's observations were made at Nash Mills during the years 1835-1853. All the observations except those of Messrs. Lawes and Gilbert were made with the Dalton gauge, artificially filled with soil or other material, Dr. Dalton's and Mr. Dickinson's gauges having an overflow-pipe, the water from which is included in the percolation given in the tables, and the other gauges being so arranged that no overflow could take place. Messrs. Lawes and Gilbert's experiments were made on the ground in its natural state of consolidation. This was effected by undermining a mass of soil, inserting a perforated iron plate below it, and then building round the mass of soil on all sides with brick in cement.

An examination of the Table shows that, with the exception of Greaves' observations on sand, the results are remarkably accordant with one another, considering the different times and conditions under which they were made. In the case of the sand, the amount of percolation is so very much larger than in any of the other cases, that at first one is almost inclined to think there must be some error. There is, however, no reason to doubt the accuracy of the observations, as they were carried out in the most careful manner by an accurate observer. They are also to a certain extent confirmed by some experiments on a small scale made by Professor Prestwich, F.R.S., who found that water filtered through sand of the Lower Greensand formation four and a half times as rapidly as through ordinary surface soil. At the same time, until there have been further experiments, it would hardly be safe to take the results given by the sand-gauge as an indication of the amount of water to be obtained by percolation through a sandy soil in its natural condition.

Before leaving the Table it may be as well to say a few words in explanation of the figures called "difference or loss." There are two ways of expressing the relation between the percolation and the rainfall. One way is to give the percolation as a proportion of the rainfall—to say, for instance, that it is one-fourth of the rainfall, one-third of the rainfall, 20 per cent. of the rainfall, and so on. The other way is to subtract the percolation from the rainfall, and to say that the yearly percolation is so many inches less than the yearly rainfall. The difference between the rainfall and percolation, or "loss," is chiefly due to evaporation, but also includes the water that is absorbed by vegetation. As previously stated, in no case is any of the loss due to surface overflow.

Although the average percolation for a series of years is fairly constant in the same district, the percolation in different years varies immensely. This is well shown by the observations carried out by Mr. John Evans, F.R.S., at Nash Mills, which, so far as we know, form the most complete series of observations on Dalton gauges in existence.

The observations at Nash Mills were originally started by Mr. Dickinson in 1835, and carried on by him until 1853, and the results are given in Table I. In the year 1853 two new gauges were put up by Mr. Evans, one filled with soil and the other with chalk. The percolation through these two gauges has been recorded

continuously by Mr. Evans ever since, and we are indebted to him for the particulars in Table II., which gives the entire series of observations on the gauge filled with chalk.

TABLE II.

Rainfall and Percolation at Nash Mills, Hemel Hempstead, for Twenty-nine Years.

Year.	Winter.			Summer.			Entire Year.		
	Rain.	Percolation.	Difference or Loss.	Rain.	Percolation.	Difference or Loss.	Rain.	Percolation.	Difference or Loss.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1853–4	9·66	5·00	4·66	9·47	—	9·47	19·13	5·00	14·13
1854–5	9·32	3·45	5·87	12·66	2·30	10·36	21·98	5·75	16·23
1855–6	14·48	10·47	4·01	14·86	3·09	11·77	29·34	13·56	15·78
1856–7	11·96	7·19	4·77	14·11	1·32	12·79	26·07	8·51	17·56
1857–8	11·81	7·16	4·65	12·27	0·84	11·43	24·08	8·00	16·08
1858–9	9·64	2·69	6·95	18·31	4·22	14·09	27·95	6.91	21·04
1859–60	16·49	12·44	4·05	20·40	8·94	11·46	36·89	21·38	15·51
1860–1	11·56	7·55	4·01	10·38	1·02	9·36	21·94	8·57	13·37
1861–2	12·63	8·19	4·44	14·37	1·77	12·60	27·00	9·96	17·04
1862–3	11·01	5·50	5·51	13·40	0·19	13·21	24·41	5·69	18·72
1863–4	9·24	5·89	3·35	8·42	0·45	7·97	17·66	6·34	11·32
1864–5	10·93	3·55	7·38	12·60	—	12·60	23·53	3·55	19·98
1865–6	20·00	12·05	7·95	15·59	0·20	15·39	35·59	12·25	23·34
1866–7	12·60	6·97	5·63	14·37	1·39	12·98	26·97	8·36	18·61
1867–8	11·36	5·36	6·00	10·05	0·42	9·63	21·41	5·78	15·63
1868–9	17·58	11·21	6·37	12·80	2·00	10·80	30·38	13·21	17·17
1869–70	13·33	8·76	4·57	7·59	—	7·59	20·92	8·76	12·16
1870–1	12·54	5·35	7·19	16·09	1·72	14·37	28·63	7·07	21·56
1871–2	11·25	9·50	1·75	14·44	2·70	11·74	25·69	12·20	13·49
1872–3	21·55	16·05	5·50	11·29	—	11·29	32·84	16·05	16·79
1873-4	8·91	4·40	4·51	10·71	0·65	10·06	19·62	5·05	14·57
1874–5	11·69	5·57	6·12	15·00	3·46	11·54	26·69	9·03	17·66
1875–6	17·28	10·29	6·99	14·25	1·15	13·10	31·53	11·44	20·09
1876–7	20·69	11·77	8·92	13·74	1·60	12·14	34·43	13·37	21·06
1877–8	13·74	8·91	4·83	18.46	5·11	13·35	32·20	14·02	18·18
1878–9	14·62	7·94	6·68	25·09	12·82	12·27	39·71	20·76	18·95
1879–80	5·84	4·28	1·56	16·40	3·20	13·20	22·24	7·48	14·76
1880–1	20·07	16·36	3·71	14·85	—	14·85	34·92	16·36	18·56
1881–2	14·82	11·38	3·44	16·52	2·64	13·88	31·34	14·02	17·32
Averages...	13·33	8·11	5·22	14·09	2·18	11·91	27·42	10·29	17·13

It will be noticed that the average percolation for the 29 years does not vary much from the average for seven years given in Table I. (see column headed Evans, Chalk), but that the percolation in different years varies immensely, the general result being as follows:—

	Maximum	Minimum.	Average.
Winter	16·36 ...	2·69 ...	8·11
Summer	12·82 ...	0·00 ...	2·18
Entire Year	21·38 ...	3·55 ..	10·29

On examining the separate years in Table II. we see that the percolation almost always increases as the rainfall increases; but beyond this it does not appear to follow any general rule, and certainly does not bear any fixed proportion to the rainfall. For instance, taking the winter first, and comparing the percolation with

the rainfall in different years, it will be seen that the percolation is sometimes less than one-third of the rainfall, and sometimes more than three-quarters of the rainfall. In the summer the proportion between the percolation and the rainfall is still more irregular. Sometimes there is no percolation at all, though there is a considerable amount of rainfall; at other times the percolation is a very small fraction of the rainfall; and, again, at other times it is a considerable fraction, varying from one-quarter to more than one-half.

From what has just been stated, it would seem as if no fixed relation at all existed between the percolation and the rainfall; this, however, would be a wrong conclusion. A careful examination of Table II. will show that, although the rainfall and percolation vary so immensely in different years, the figures in the column headed "difference or loss" only vary very slightly. This is specially noticeable in the summer, where, if a few exceptional cases were excluded, it might be said that this "difference or loss" is almost constant.

This view of the question throws quite a different light on the subject, and shows that the point to be looked at is not the *ratio*, but the *difference*, between the percolation and the rainfall, and that this difference is fairly constant. This simple principle at once explains many of the apparent anomalies in Table II. For instance, taking summer, where the proportion between the percolation and rainfall was so extremely irregular that nothing could be made out of it, and assuming that the constant loss is 12 inches, it will at once be seen that the reason why the percolation in some years is nothing, is that the rainfall is less than the loss, or, in other words, that all the rain is evaporated.

The above rule in conjunction with Table I. will also give a means of approximating to the percolation where no observations have been made. In the first place it will be necessary to obtain the value for "loss," which varies under different circumstances. From Table I., however, it will be seen that if due regard is paid to the season, the variation (except in the case of sand, which has previously been remarked on) is not very great. It will generally, therefore, be sufficient to obtain the "loss" from Table I., care being taken to select the case which corresponds most nearly with that under consideration. By subtracting the assumed "loss" from the known rainfall, a useful approximation will be obtained to the percolation. If the "loss" is greater than the rainfall, as is sometimes the case in summer, we must conclude that the whole of the rainfall has been evaporated, so that no percolation took place.

There are some exceptional cases to which the above rule will not apply, and these can, to a great extent, be accounted for by differences in the amount of rain which has fallen in the months immediately preceding the season under consideration. The two most exceptional winters in Table II. are explained in this way: In 1871–72, the winter rainfall was 11·25, and the percolation should, therefore, by the preceding rule have been about six or seven inches, whereas it really was 9·50 inches. On examining the details of the monthly rainfall, we find that there had been an exceptionally heavy fall in the preceding September, so that the ground was thoroughly saturated at the commencement of the winter of 1871–72. In 1879–80 again the winter rainfall was only 5·84 inches, and the percolation, therefore, should have been under one inch, whereas it really was 4·25 inches. Here also September as well as the three preceding months had been exceedingly wet.

From the examples which have just been given, as well as from what has been previously said, it will be seen that the amount of percolation does not depend so much on the amount of the rain as on the conditions under which it falls. A heavy fall of rain in summer will generally give no percolation at all, whereas the same fall in winter will give a large amount of percolation, the reason being that in summer the ground is dry, and the rain is all evaporated or taken up by vegetation, whereas in winter the ground is wet, and evaporation comparatively small, so that a large proportion of the rain sinks into the ground. Even in winter the amount that percolates will vary with the condition of the ground. If there has been a dry autumn the percolation in winter will be comparatively small, but if there has been a wet autumn, so that the ground is thoroughly saturated, the percolation in the succeeding winter will be large.

CHAPTER LXXX.

MOVEMENT OF UNDERGROUND WATER, SPRINGS, AND WELLS.

Variation of Level of Underground Water—Comparison with Percolation—Movement of Underground Water—Springs—Method of Gauging—Wells—Contamination—Examples from Hydrographical Survey—Effect of Pumping—Distance to which Influence of Pumping extends.

THE variations which occur in the height of the underground water at different seasons are fully in accord with the results obtained by the percolation-gauges. It is a matter of common knowledge to those who have to draw water by a bucket from a deep well in the chalk that the water in the well is much lower in autumn than it is in winter. Closer observation shows that the level of the water in the well is generally at its lowest in October or November, that it then rises rapidly till February or March, when it reaches its highest level, and that after this it gradually falls again till the following autumn. Hence the period of rise of the water-level corresponds very nearly with the period of greatest percolation, and the period of fall with the period of least percolation.

The relation between the percolation and the underground water-level in different years, and different seasons, is so instructive that we have prepared the diagram, Fig. 383 (on the next page), from observations that have been made on a well in a chalk district. The well in question is at Chilgrove, near Chichester, where observations have been recorded regularly for nearly half a century, and we are indebted to Mr. J. W. Woods for the measurements during the ten years shown on the diagram. The upper zigzag line gives the depth of the water in the well for each month, the bottom of the well being shown by a horizontal line. The dark spaces rising from the bottom of the diagram represent the percolation, and the light line running just above shows the rainfall. The depth of the water in the well is given in feet, and the rainfall and percolation in inches, as shown by the scales at the side of the diagram. The rainfall is taken from observations at Chilgrove, and the percolation is deduced from the observations at Nash Mills (see page 809).

The first noticeable general feature in the diagram is that the great bulk of the percolation takes place in the winter, and hardly any at all in the summer, except in the case of the year 1879, to be mentioned hereafter. Thus in the summers of 1873–74–77–78–81 there was a considerable amount of rain, but this rainfall did not give any percolation.

In the next place it will be seen from the upper zigzag line in the diagram, that the fluctuations of the water-level, with one exception, follow the general rule already mentioned. The water-level is at its highest early in the year (February or March), falls throughout the summer, is lowest in October or November, and then begins to rise again. It will also be observed that the rise in the water-level of the well follows the percolation with great regularity, but that a short interval always intervenes. For instance, if the winter percolation commences in October, the water does not begin to rise in the well until November; and if the percolation obtains its maximum in January, the water in the well does not attain its maximum

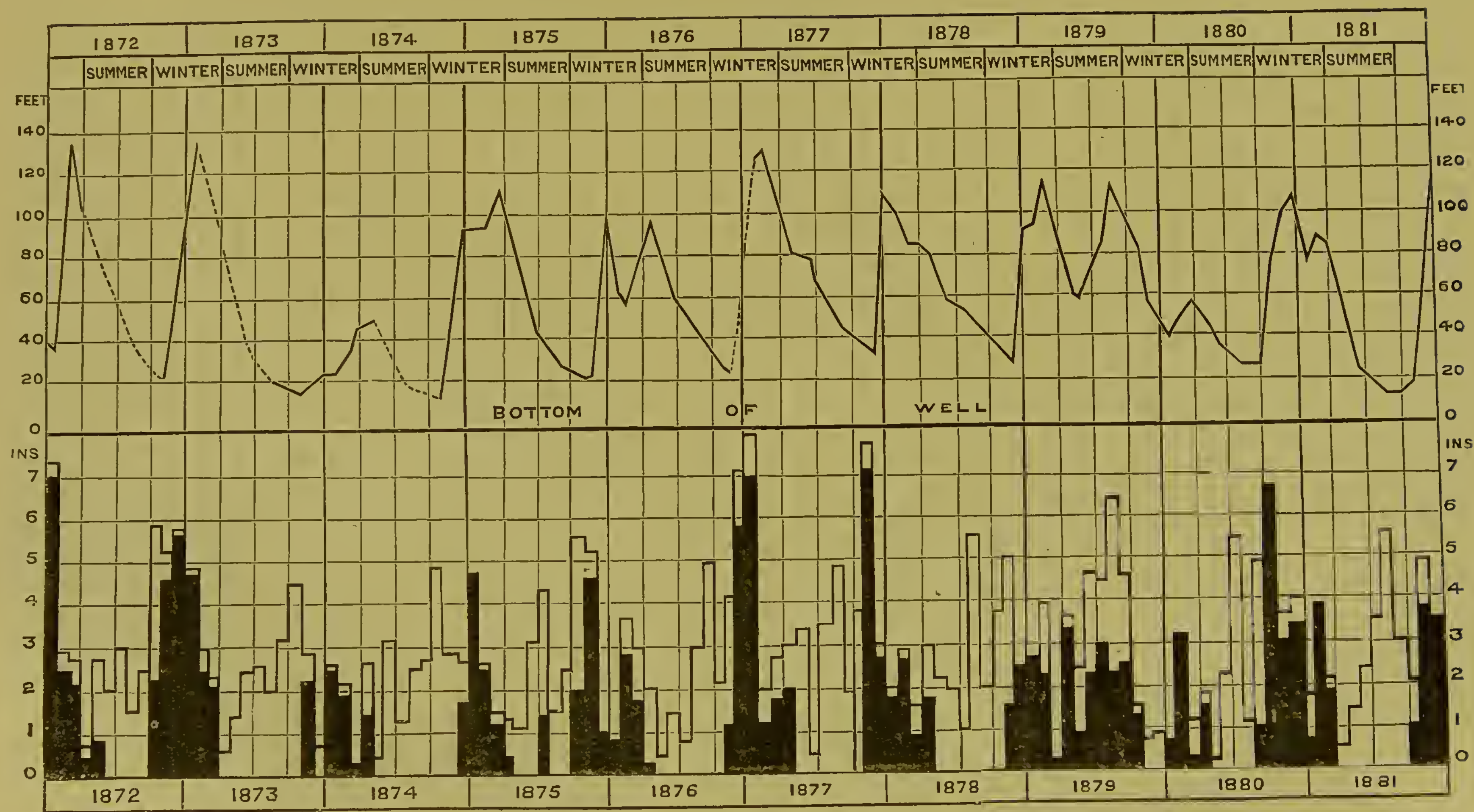
1872 1873 1874 1875 1876 1877 1878 1879 1880 1881
SUMMER WINTER SUMMER WINTER SUMMER WINTER SUMMER WINTER SUMMER WINTER SUMMER WINTER SUMMER WINTER SUMMER WINTER SUMMER WINTER SUMMER
FEET
140 120 100 80 60 40 20 0
BOTTOM OF WELL
INS
7 6 5 4 3 2 1 0

Fig. 383.

till February or March. From this we should conclude that in a chalk district like that under consideration, from one to two months elapses before the percolation affects the level of the underground water. We also see that winters in which there is a minimum of percolation, such as those of 1873–74, 1879–80, have also the lowest water-level; while the winters in which there is a maximum percolation, such as 1872–73, 1876–77, have the highest water-level.

As previously mentioned, the year 1879 is very exceptional in having a large amount of summer percolation, and on looking at the upper zigzag line, it will be seen that this year is also exceptional in having a double rise in the water-level, one occurring early in the year and the other at the end of the summer. It will be seen, moreover, that the summer rise follows the summer percolation in the same way that the winter rise follows the winter percolation.

The variation which takes place in the level of the underground water between autumn and winter may be called the "seasonal variation"—its extent is very different in different cases. In the upper districts of the chalk, this seasonal variation is frequently 50 feet, and sometimes considerably over 100 feet, whereas in the lower districts it may only be three or four feet. In the New Red and Old Red Sandstones the seasonal variation is considerably less in amount than in the chalk.

In order to explain the reason of this great difference in the amount of the seasonal variations of level of the underground water in different localities, we must consider the question of the movement of underground water. This question is of primary importance from a sanitary point of view, not only with reference to the amount of water obtainable from wells and springs, but also with reference to the conditions which favour or otherwise the pollution of the water-supply by cesspools and drains. We, therefore, propose to consider the question somewhat in detail, more especially as its great importance is often not sufficiently realised.

The movement of underground water has been more fully investigated on the Continent than it has in England, particularly in connection with what are called natural filter-galleries, by which many large towns on the Continent are supplied. These filter-galleries, which were constructed of porous brickwork, were laid parallel to a river at a greater depth than its bed, the idea being that when the water in the filter-galleries was pumped the river-water would percolate into the gallery, and thus be purified. The results were found, however, to be very irregular, some of the galleries working very satisfactorily and others soon silting up. This led to very elaborate investigations, the outcome of which was that the galleries which were successful were proved not to draw their supply from the river, but from an independent source. Not only was the temperature of the water pumped from the galleries different from that of the river, but the chemical constituents were also different. Further investigation proved the existence of a general flow of underground water passing from the higher grounds into the bed of the river, and showed that this, not the river, was the source from which the galleries were fed. An extensive series of official experiments with reference to questions affecting the sewerage of Berlin, also proved that the underground water had a continuous flow towards the river Spree, and that the idea previously held that the water of the river forced itself into the subsoil and caused the contamination of the wells was an entire mistake, as the contamination proceeded, not from the river, but from the pollution of the ground underneath the houses.

In England, filter-galleries near rivers have been very little used, and we are not aware of any experiments on them; but observations which have been made on permeable formations near the sea show that a movement of underground water is generally taking place from the land towards the sea. A good illustration of this is given in a paper by Mr. Edward Easton, on the waterworks at Brighton, which, as is well known, is situated on the chalk formation. He states that one of the most striking features of the country near this town is an entire absence of all streams and watercourses. There are plenty of natural basins and valleys, but no water at all is visible in them; and even after a heavy storm the rain disappears almost as quickly as it falls, so rapidly is it absorbed by the ground. On examining the shore at low water numerous rills are seen to be flowing from the higher parts of the beach through the shingle, and on testing them they are found to consist of

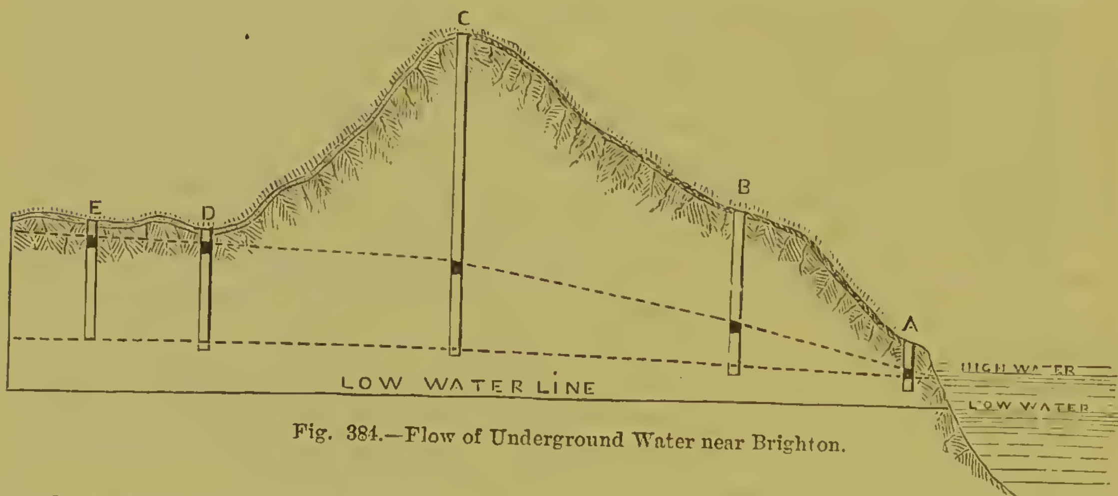

Fig. 384.—Flow of Underground Water near Brighton.

fresh spring-water. These rills are always running, the only variation that is perceptible being a slight increase in winter and a decrease in summer. Further, on measuring a number of wells so as to ascertain the level of the underground water in the chalk, it is found that this water has a regular fall from the land towards the sea. The natural conclusion from these facts is that the rain which is absorbed by the ground gradually finds its way through the pores and fissures in the chalk to the sea; and advantage has been taken of these circumstances to obtain a water-supply for Brighton. Deep tunnels have been driven in the chalk parallel to the sea-coast at about the level of low water, so as to intercept the underground streams, and by this means a very ample supply of water has been obtained.

The course of the rainfall in its passage to the sea is illustrated by Fig. 384, which is a section at right angles to the shore-line, showing the actual measurements of the wells taken from the above paper. The lower dotted line through the bottom of the wells A, B, C, D, E, represents the level of the underground water when the wells are at their lowest (usually in October or November), and may be called the line of permanent saturation. The upper dotted line represents the water-level when the wells are at their highest (usually in February or March). Several important facts are shown by the section. In the first place we see that the fall of the underground water cannot be determined from the fall of the land. The land between well C and well D has a rapid fall from right to left, but the underground water between

these wells falls from left to right. In the next place we see that the farther the wells are from the sea the greater is the variation between their summer and winter water-levels. The seasonal variation in well A is only a very few feet; in well B it is 25 feet, and in well E it is 50 feet. The section also shows the reason of this difference, viz., that the level of the water at its outlet into the sea is nearly constant, and that the levels of the intermediate wells between the sea and the farther wells are defined by a line drawn from the sea to the water in the farthest well. Lastly, the section shows that the surface of the underground water has a much more rapid fall to the sea in winter than it has in autumn. The fall of the upper, or winter water-line, is about 30 feet per mile, whereas that of the lower, or summer water-line, is less than 10 feet per mile. A greater fall, of course, means a greater velocity, and hence the flow of the underground water towards its outlet must be more rapid in winter than in autumn, thus explaining the increased flow of the springs at the sea-shore in winter.

We have gone somewhat fully into the above case, because it is an epitome of what takes place with reference to underground water generally, and also, when taken in conjunction with what has previously been said about percolation, clearly explains the origin of springs. The rain which falls on permeable strata percolates downwards until it is arrested by beds of clay or other impermeable strata. The water then accumulates and renders the impermeable strata waterlogged up to a certain line which is governed by the lowest point of natural escape. At Brighton the lowest point of escape is into the sea; in other cases it is into rivers or streams; and in others again the escape is on a hill-side, where springs burst out at the lip of the basin formed by the underlying impermeable strata. The rain which percolates into the ground does not pass immediately to the natural outlet, but is

Fig. 385.—Levels of Underground Water from Wallingford to Henley.

stored for a certain time in the water-bearing strata, and only escapes very slowly. This accounts for the fact that springs do not cease running when percolation ceases, but continue, though at a reduced rate, during the summer.

From what has been stated, it will be seen that it is a great mistake to compare the underground water to a lake, as is often done. The surface of a lake is level, whereas the surface of the underground water almost always has a fall towards its natural outlet. If there is only one outlet, or line of outlets, the underground water may be compared to an inclined plane. If, on the other hand, as is often the

case, there are several outlets in different directions, the underground water may be more correctly compared to a low-swelling hill, as will be seen by an examination of Fig. 385, which represents a section from the River Thames near Wallingford through the Chiltern Hills to the River Thames below Henley. Between these two points the river makes a complete horse-shoe bend of many miles, affording outlets for the underground water from the chalk at numerous places. It will be noticed that there are various dotted lines from river to river; the lower of these represents the lowest level to which the underground water falls, and the upper line represents the highest water-level in winter. Both these lines are convex, showing a fall each way to the river; but this fall is much less on the lower line than on the upper line.

SPRINGS.

The intermittent springs, or "bournes," as they are often called, which occur in different parts of the country, are also well illustrated by Fig. 385. It used to be imagined that these intermittent springs were due to syphons formed by hidden channels in the ground. These syphons were supposed to empty underground reservoirs, and then to cease to act until the reservoirs were full again; and in some works on geology and on water-supply, figures are found of these supposed syphons. As far as we know, however, no such syphon has ever been discovered, nor have any facts been brought to light supporting this supposition. At any rate, the ordinary bournes are perfectly explained by the known laws which regulate the movement of underground water, and their occurrence can be predicted by attention to these laws.

From Fig. 385 it will be seen that at the point marked "Assenton Spring" there is such a deep valley that when the water-level rises to the upper line it is above the ground. The consequence is that under these circumstances large quantities of water issue from the chalk and form a surface stream, called Assenton Spring. This spring does not flow every year, but at irregular intervals, often of several years. When it does flow it usually commences about December or January, and ceases to flow in the summer, but in the year 1879 it surprised the neighbourhood by breaking out in June and continuing to flow for several months. On referring to the diagram, page 813, and to Table II., page 809, it will be seen that 1879 is the exceptional year already more than once referred to, in which there was a large amount of percolation in the summer, followed by a rapid rise of the underground water. This fully accounts for the "breaking" of the spring, which is in reality nothing more than the overflow of the underground water when it rises above the level of the ground. When the seasonal rise of the underground water is not sufficent to bring it above the level of the ground, then there is no outburst of the spring. By carefully observing the rise of the underground water, as shown by wells in the valleys where bournes occur, their appearance can be predicted with the greatest certainty, and this has actually been done in many cases.

The variations which take place in ordinary springs are to a great extent explained by the preceding considerations. Springs are frequently divided into land springs and main springs, the former term being applied to springs of water flowing from superficial beds of drift or gravel, lying on an impervious substratum, and the latter term to deep-seated springs found in the chalk, greensand, sandstone,

or other regular geological formations. In the case of shallow land-springs the flow is often very irregular; the superficial beds being more rapidly exhausted, and also more rapidly replenished than the deeper water-bearing strata. Careful observations have shown that sand and gravel are replenished by heavy summer showers, which would produce no effect at all on deep-seated springs. This is explained by the large amount of *summer* percolation found in the sand-gauge in Table I., page 807. Even in these shallow springs, however, there is a marked seasonal variation, the springs being generally at their lowest in October and November, and at their highest in February and March. The deeper seated the springs are, the more regular, as a rule, is the seasonal variation. The main springs vary much less than the land springs, and are often stated to yield an undeviating volume. Careful measurements, however, show a regular seasonal variation corresponding with what has been stated above. As an example of this, it may be mentioned that a series of gaugings of a chalk spring in Buckinghamshire, extending over a number of years, show such a remarkable agreement with the recorded percolation at Nash Mills, that the yield of the spring might almost be calculated from the percolation gauge.

It is most important to give due attention to this seasonal variation in the flow, when selecting a spring for the water-supply of a house. If the selection is made early in the year, it may be found in autumn that the yield of the spring has been reduced to such an extent as to be altogether insufficient for the supply of the house. Unless the yield of a spring is very much in excess of the supply required, it is never safe to depend upon it until its yield in autumn has been ascertained, and even then one may be misled unless close regard is paid to the nature of the season—that is to say, whether or not the rainfall has been such as to cause an unusual amount of percolation.

Before selecting a spring for the supply of a house or homestead, it ought therefore to be carefully gauged at intervals during summer and autumn. If the spring is only very small the method explained at page 785 may do; but if the flow is of moderate amount, some other means must be adopted. The most convenient method is that usually employed by engineers, namely, to fix a "notch-board" across the spring or stream. Fig. 386 shows a notch-board fixed across a stream for the purpose of ascertaining its flow. The notch-board *a*, having a rectangular notch with chamfered lip and edges as shown on the sketch and section, is placed at a convenient point in the stream, and properly clay-puddled into the banks and bottom of the stream, and made secure, so that all the water runs through the notch. The size of the notch required must be roughly estimated so that it takes the flow of the stream with a few inches depth over the lip of the notch. Where greater accuracy is required in making the measurement, it is a good plan to have the notch made in a thin sheet of metal. In order to calculate the flow over the notch, it is necessary to measure the depth of the *still water-surface* over the lip of the notch. This cannot be done at the notch-board itself, as the water in running over the notch assumes a curved form, as shown on the section. It is therefore usual to drive a stake, as at *c*, situated some distance from the notch, where the water is still, and measure the depth there. The distance at which the stake must be driven from the board will depend, of course, on the size of the notch used, but generally four or five feet will do. A ledge is cut upon the stake, which

is driven until the ledge is exactly level with the lip b of the weir, as shown on the section, and from this ledge the depth of water may be measured in inches with

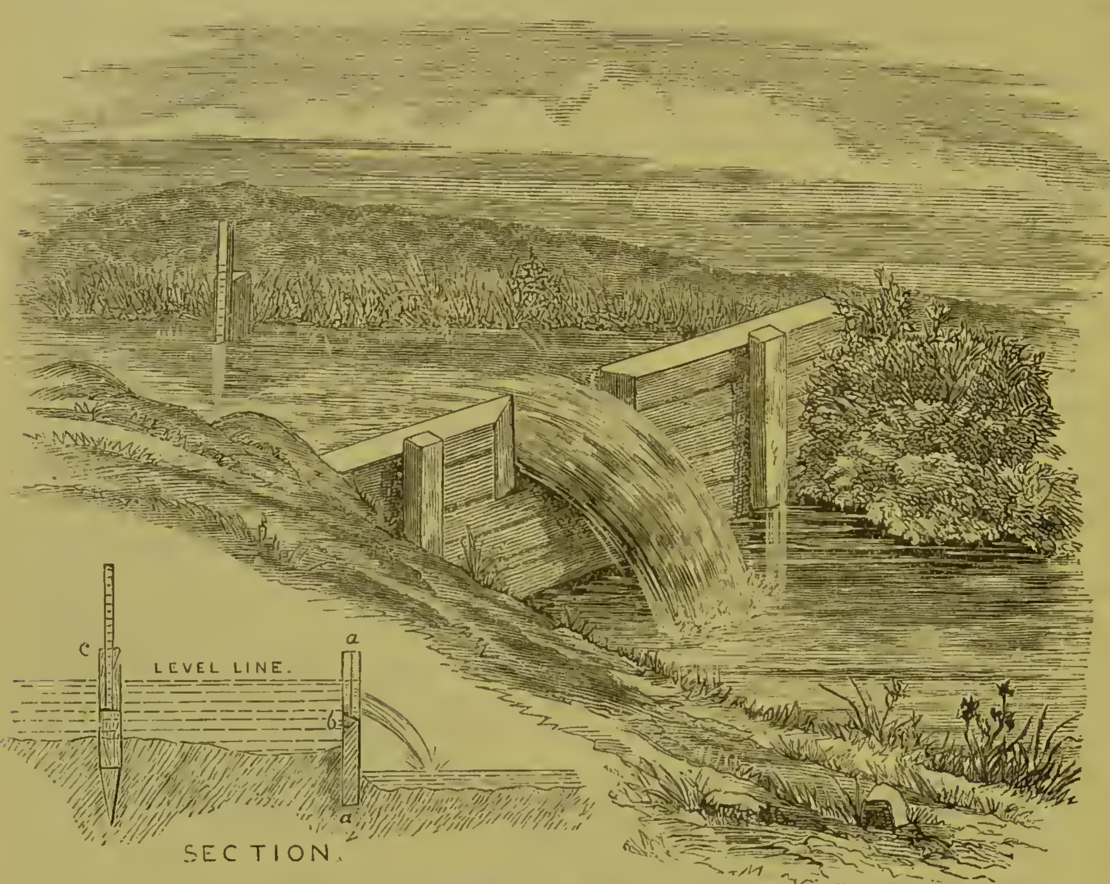

Fig. 386.—Notch-board.

the ordinary rule. The notch-board must be fixed at a point on the stream where a proper fall can be obtained, as shown on the sketch. The chamfered lip, b, should also be well above the bed of the stream, as shown in the section.

TABLE III.

Depth in Inches.	Gallons per Minute.	Depth in Inches.	Gallons per Minute.	Depth in Inches.	Gallons per Minute.	Depth in Inches.	Gallons per Minute.
$\frac{1}{4}$	·31	$1\frac{3}{4}$	5·76	$3\frac{1}{4}$	14·6	$4\frac{3}{4}$	25·8
$\frac{1}{2}$	·88	2	7·04	$3\frac{1}{2}$	16·3	5	27·8
$\frac{3}{4}$	1·62	$2\frac{1}{4}$	8·4	$3\frac{3}{4}$	18·1	$5\frac{1}{4}$	29·9
1	2·49	$2\frac{1}{2}$	9·8	4	19·9	$5\frac{1}{2}$	32·1
$1\frac{1}{4}$	3·48	$2\frac{3}{4}$	11·3	$4\frac{1}{4}$	21·8	$5\frac{3}{4}$	34.3
$1\frac{1}{2}$	4·57	3	12·9	$4\frac{1}{2}$	23·8	6	36·6

Table III. gives the discharge in gallons per minute over a notch-board one inch wide, for depths increasing by quarter-inches. To give an example of the use of this Table, we will take a notch 4 inches wide between the sharp angles of the

chamfers, and having measured at C the depth of the flow over the lip of the weir, we find it, say, $1\frac{1}{4}$ inches. Referring now to the Table under $1\frac{1}{4}$ inches, we see the amount 3·48 gallons, and, as this is for a weir 1 inch wide, we must multiply by 4 for a weir 4 inches wide, giving 13·9 gallons per minute, or 20,000 gallons per diem.

WELLS.

As has been stated in the first part of this article, wells may be divided into two classes—shallow wells and deep wells. The distinction between the two is not very clearly defined, but it may be considered generally to depend more on their nature than their depth; shallow wells being those which are sunk into a superficial bed of drift sand or gravel resting on an impervious stratum, and deep wells those which are sunk into the regular geological formation, such as chalk, greensand, sandstone, &c. In fact, the distinction between shallow wells and deep wells is very much the same as that between land springs and main springs.

Shallow wells are very properly looked on with suspicion, on account of their liability to pollution. At the same time, there are a great many situations in which almost the only practicable method of obtaining a water-supply is by means of more or less shallow wells, and it is, therefore, of importance to consider the conditions which affect their supply, both as regards quality and quantity. Moreover, proper attention to these conditions will often render it possible to obtain a very good supply from shallow wells; whereas inattention to them will lead to disastrous results.

The great danger, in the case of shallow wells, is that they may be contaminated by soakage from cesspools or drains. The extent of this danger is not even yet sufficiently appreciated by the general public, and we will, therefore, go into a few particulars about it. Such gross cases of contamination from cesspools as the one explained on page 714 are so palpable, that people are beginning to understand *their* danger, and it is not, therefore, necessary to say more about them than what has already been said by Dr. Corfield. This pernicious practice is, however, often carried out in a way in which its danger is by no means apparent, and yet so widespread that Prof. Prestwich says no one who has not gone into the geological question can realise its magnitude. The question has been so admirably treated by the same high authority that we cannot do better than quote his own words :—

"Let us take a section of any permeable stratum, such as *a*, Fig. 387, underlaid by another, *b*, which is impermeable. (The illustration will apply to any case where water is obtained by means of ordinary wells, whatever their depth.) As before mentioned, a certain portion of the rain which falls on the surface sinks down through *a*, until stopped by *b*, where it stands, and rises to a certain level, *l*.

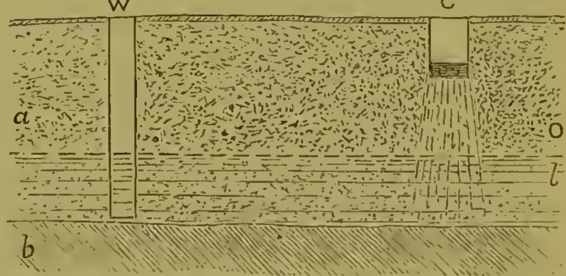

Fig. 387.

"Any shaft—such, for example, as W—sunk in *a* to below the water-level, *l*, will, when it passes into the water-charged portion of the gravel or sand, *a*, have the

water in the gravel or spring flow into it, until it reaches the level, *l*; and as quickly as the water is removed or pumped out of W it is replenished from the surrounding store in the gravel, *a*, the height of the water in W being maintained consequently at that of the line *l*. If, on the other hand, another shorter shaft or pit be sunk at C to any point higher than the level *l*, no water will rise into that shaft, and it will remain always dry. On the contrary, if water or any liquid refuse be poured into C—which is constructed of bricks without mortar, so as to allow of free drainage into the surrounding gravel—it will pass down, like the rainfall, to the main body of water or spring at and below *l*, and will never lodge at the level O, but drain down and add to the general store below *l*.

"This property of permeable strata has, for ages, been taken advantage of for the double purpose of obtaining a ready water-supply and a ready house-drainage; and it is a disgrace to the civilisation of the nineteenth century that a practice, begun long ago in ignorance and amongst a scanty population, should have been allowed to continue unchanged and in its primitive rudeness, with all our knowledge and experience, and amongst our teeming population. With, however, builders and architects—too often ignorant of the consequences, and wishful to hide a nuisance, prompted, too, by the facility with which it is done—the abuse has continued, and seems likely to continue, for the arrangements are naturally kept as much as possible out of sight, and, being out of sight, it rarely occurs to any one without cause to inquire where or how they are made."

Prof. Prestwich then gives a section of the village of New Hincksey, near Oxford, as it existed in 1876, which we reproduce in Fig. 388, as it is a striking

Fig. 388.

illustration of the way in which cesspools and wells are intermixed, without any consideration whatever of the inevitable result. The short vertical shafts are the cesspools, and the longer vertical ones reaching to the underground water are the wells. Very probably the sewage, in its slow percolation through the gravel, becomes so filtered and aerated before it reaches the underground water, and is then mixed with such a large volume of this water, that the supply from the wells is clear and sparkling; but it is none the less dangerous. In fact, *the entire bed of water under the village is polluted*, and *no* precautions that can be taken in sinking the wells will enable a safe supply from it to be obtained.

If there is only one well and one cesspool, as in Fig. 387, at some distance from each other, the case is quite different, and whether the well is polluted or not will depend chiefly on the direction of the flow of the underground water. If this flow is from C to W, the water which has been polluted by the percolation from the cesspool will be carried towards the well and contaminate it; whereas, if the flow is from W to C, the polluted water will be carried away from the well, which will then draw its supply from the pure underground water flowing from *a* to W. If any large quantity of water is pumped from the well it may alter the state of affairs, as will

be explained hereafter; but leaving this out of consideration for the present, it may be stated, as a general rule, that wells which have cesspools or other sources of contamination above them are always dangerous, whereas those which have cesspools below them may be safe. It must be clearly understood, however, that the terms "above" and "below" have reference to the fall of the underground water, not to the fall of the land; which, as already explained, may be quite different from that of the underground water.

The well-known engineer, Mr. Baldwin Latham, in a paper he read before the British Association in 1876, gives some striking examples of the influence of the flow of the underground water on the pollution of wells, one of which we will quote. He states that when called upon by the Croydon Local Board to inquire into the state of the health of the inhabitants of a cluster of sixty-nine houses, situated in the hamlet of Wallington, near to the Sewage Irrigation Works of the Croydon Local Board, he reported that in all the houses in which the cesspools were placed on the north of the habitations, the tenants had been, as far as was known to the present inhabitants, entirely free from any zymotic disease, whilst in those with cesspools located in other aspects the tenants had suffered at various times from different kinds of zymotic disease. At that time the author attributed it to the effect of the prevailing winds wafting any miasms in the direction of these houses; but more careful investigation showed, with respect to these houses, that the current of underground water was from south-east to north-west, and that the well and cesspool were invariably on opposite sides of the house, so that if the cesspool was on the north, the well was on the south, and, therefore, located above the cesspool, as respects the fall of the subterranean water. In such cases the house had been invariably healthy; but in every case in which the cesspool was located above the well, that house had never been long free from enteric fever so long as the water from the well was in use; in fact, the use of water from most of the wells so located had been prohibited by the doctors in attendance on the occupants of these houses.

From what has just been said, it will be seen that the very first circumstance that should be investigated with reference to a shallow well is the direction of the flow of the underground water. This can generally be approximately ascertained by an examination of the locality, and paying attention to the circumstances which, as previously explained, affect the underground flow. The conclusions, however, which are thus arrived at should always be checked by taking the levels of the water in existing wells and springs. The direction of the underground current, besides showing how to locate the well so as to avoid contamination, will also afford a rough indication of the area from which the well will draw its supply. This, in many cases, will enable some idea to be formed as to whether the supply is likely to be sufficient or not. For instance, as explained on page 818, the underground water sometimes takes the form of a low swelling hill, and, in such cases, a well placed near the summit of this hill of water would be much less likely to have a good supply than one placed lower down.

Another point which it is very useful to ascertain is the amount of the seasonal variations in the level of the underground water. This is of importance for two reasons. In the first place, it is essential that the bottom of the well should be below the lowest level to which the underground water falls, otherwise it will run

dry. In the next place, when the seasonal variation is large, a reliable supply is, as a rule, less likely to be obtained than when the seasonal variation is small. Information can often be obtained with reference to the seasonal variation by inquiries as to existing wells. Shallow wells are not generally sunk deeper than necessary in the first instance, so that, if it is found that a well has not been known to fail, it may be assumed that the bottom of the well is a few feet below the lowest water-level. A well where water is drawn by a bucket is particularly valuable in such inquiries, as the length of the chain will give an idea as to the lowest level of the water, and probably the person who draws the water can give some information as to the amount the chain has to be unwound when the water is high.

In the hydrographical survey made by Herr Thiem when investigating the underground water-system in the neighbourhood of Leipzig, with a view to obtain a supply of water for that town, many interesting facts were ascertained which explain cases often occurring in sinking wells for houses. For instance, it sometimes happens that, when a well has been deepened in order to improve the supply, the water is entirely lost by such process; and the reverse case also occurs, where a well, originally dry, has yielded a good supply on certain strata being penetrated. The following are examples of local irregularities observed in the course of the hydrographical survey at Leipzig.

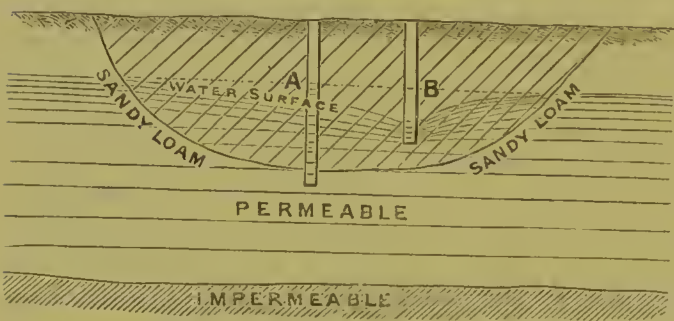

Fig. 389.

The case in Fig. 389 is that of a slightly permeable bed of sandy loam lying on a freely-permeable stratum of more or less coarse diluvial gravel. Well A, which will be seen from the diagram to pass through the loam into the permeable stratum, has a water-level corresponding with the general underground water of the district, while well B, which does not pass completely through the loam, has a water-level which varies greatly with the amount drawn out. This is due to the friction which the water meets with in its passage through the partly impermeable strata.

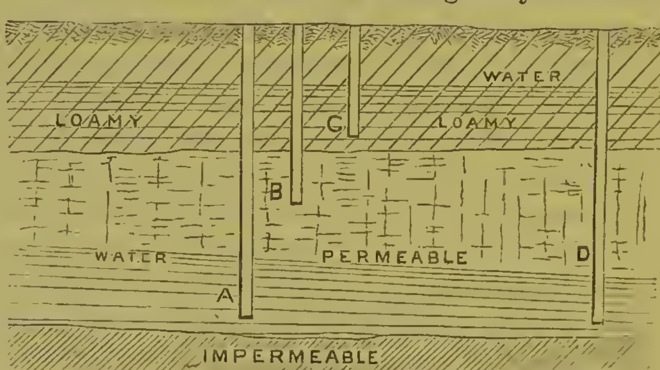

Fig. 390.

Fig. 390 shows a case where the loamy bed has great horizontal extension, having below it permeable beds of coarse gravel. Rain falling upon the surface percolates into the loam, and forms a sheet of water which owes its continuity to the slight porosity of the loam. The level of this water is constantly varying, because this suspended water, as we may call it, is slowly percolating through the loam into the lower permeable stratum, and, as soon as it

reaches this, it falls through to the lower water-bed, where it forms a second bed of water at a lower level, as shown on the diagram. Wells sunk in the positions A, B, and C will all give different results. Well A will constantly yield water. Well B will not yield any water at all, as, directly the well is carried through the loam, the water will be lost. Well C will only yield water as long as fresh rain falls before the water-surface in the loam has had time to sink to the bottom of the well, in consequence of the percolation which is always slowly going on through the loam. The water-level in wells A and D may be gradually lowering while the water-level of well C may be rapidly rising, owing to rain falling and replenishing the upper beds.

Fig. 391 shows a case where a bed of slightly-pervious sandy loam has a thin bed of clay underneath it, which offers very great resistance to the percolation of the

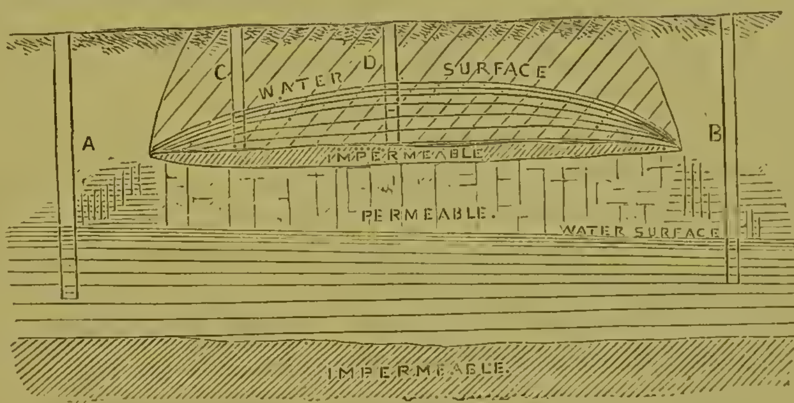

Fig. 391.

water The bed of loam and clay forms a sort of island in a permeable stratum. the underground water in which flows from left to right upon the diagram. The rain-water falling upon this island will pass down to the clay bed, and gradually run off at the extremities. As the resistance from friction to the passage of the water through the upper bed is very considerable, the surface of the water in the island will assume a curved form, being heaped up in the centre, as shown on the diagram. Wells C and D, sunk in the island, will run dry nearly at the same time;

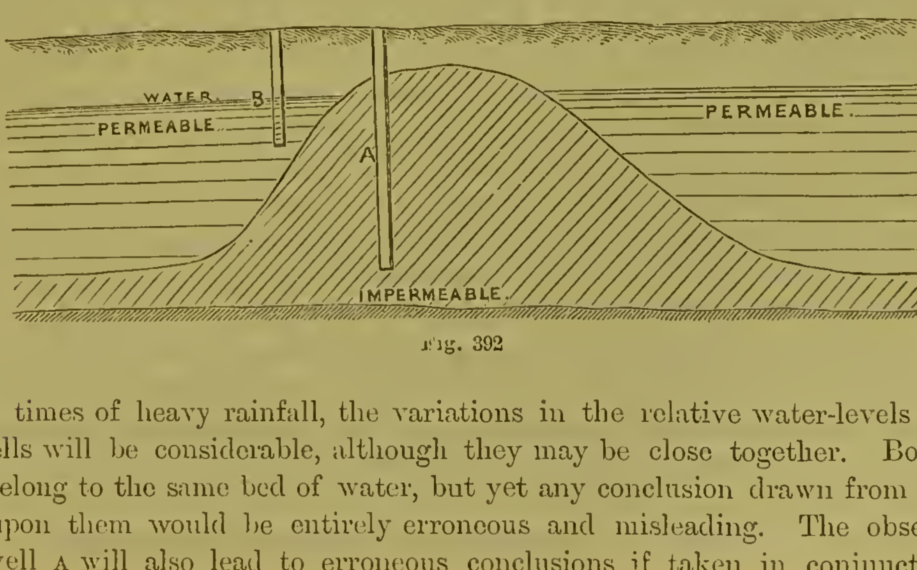

Fig. 392

but, in times of heavy rainfall, the variations in the relative water-levels of these two wells will be considerable, although they may be close together. Both these wells belong to the same bed of water, but yet any conclusion drawn from observations upon them would be entirely erroneous and misleading. The observations upon well A will also lead to erroneous conclusions if taken in conjunction with

well C or well D, and only a joint consideration of wells A and B will give the true direction and fall of the underground water.

Fig. 392 shows a hillock of impermeable strata rising from an impermeable bed up to and above the level of the underground water in the permeable stratum surrounding it. A well, such as A, sunk into the hillock will yield no supply of water, whilst a well only a short distance away, such as B, will, at a shallower depth, give a supply.

Deep wells are much less liable to contamination than shallow wells, but even they are not safe from the insidious influence of cesspools. A very striking instance of this occurred at Liverpool some years ago, in the case of the Dudlow Lane well, sunk in the New Red Sandstone formation. This well was situated in a suburban district some distance from Liverpool, and was 247 feet deep, with a bore-hole at the bottom another 196 feet deep, making 443 feet altogether. The effect of the continuous pumping from this well was to dry the wells of the houses in the neighbourhood, and these were then used in several cases by the householders as cesspools. The consequence was that the water in the Dudlow Lane well was gradually polluted, and in five years after the well was constructed it had to be disused. The following is the official report of the Water Committee on the matter :—

"In the case of the Dudlow Lane well, the Committee were compelled to cease pumping from February, 1872, to 5th May, 1873, in consequence of the dangerous extent to which the water was contaminated. It was ascertained that the evil was mainly due to percolation from cesspools and disused wells, which had been made receptacles for drainage; and the Committee caused the communication with several of these to be temporarily diverted, at the same time pressing the local authorities, and co-operating with them, to carry out a complete sewerage scheme for the district. By these measures the quality of the water was so far improved that it was brought within the limits defined by the Rivers Pollution Commission as 'reasonably safe,' and the pumping was resumed."

On looking at the various estimates that have been given of the safe distance between wells and cesspools, or other sources of pollution, we are at once struck with their extreme discordance. In the Local Government Bye Laws for the drainage of towns, it is usual to fix twenty to thirty yards as the least allowable distance of a well from a cesspool. Prof. Frankland, F.R.S., in his evidence before the Committee of the House of Commons on the Public Health Amendment Bill, says that a well should be at a distance of not less than 200 yards from a cesspool. Again, taking another source of pollution, namely, cemeteries, as to which rules have been laid down in various countries, we find that in Italy no well is allowed to be sunk within one hundred yards of any cemetery, and double this distance is required in France and Austria. This is called the "protective distance," but has in some cases been thought to be too small. The Hygienic Council at Brussels, in 1852, decided that a distance of four hundred yards was protective; but even this distance has been sometimes conceived to be inadequate. In Prussia, no cemetery may be located within five hundred paces of any dwelling. At Stralsund, in Prussia, the distance required is one thousand paces.* Lastly, a case is recorded which occurred at Lausen, in Switzerland, where the infectious matter of typhoid passed under-

* Sixth Annual Report of the State Board of Health of Massachusetts, 1875.

ground a distance of about a mile through a hill to a village on the opposite side, where it polluted the public well.

The difference between these figures is so great, that at first sight it appears waste of time to attempt to reconcile them; but a little consideration will show that they are really not so inconsistent with one another as we might suppose. In the case of the contamination at Lausen, the public well was proved to be on the direct line of flow of the underground water from the farm where the typhoid fever occurred. The underground communication, moreover, was so direct that when the land below the farm was irrigated with the water of the brook which was contaminated with the drainage of the farm, the water of the public well in Lausen became discoloured. Under these circumstances it is evident that a well placed only a short distance above the farm would be safer than one placed a mile below. This shows that any estimate of a protective distance without taking the direction of the flow of underground water into account, is altogether delusive. There is, however, also another circumstance which cannot be left out of consideration, viz., the amount of water drawn from the well. In order to draw water from a well in any considerable quantity pumping must be resorted to, and this introduces altogether a new element.

When water is pumped from a well, the effect is first of all to lower the water in the well itself, and then to lower the underground water for a certain distance all round the well. By this means a depression, of which the well is the centre, is formed in the underground water, and as far as this depression extends the underground water is drawn towards the well. The amount of the depression and the distance from which the water is drawn to the well will generally increase with the amount of pumping; so that a cesspool which may be quite beyond the influence of the well when only a small quantity of water was drawn from it might be brought within that influence when a large quantity was drawn. It therefore becomes of great importance to determine the form taken by the depression which is produced by pumping.

The literature on this subject in England is extremely limited and somewhat misleading. Probably the most important contribution to the question is the able report which Mr. Robert Stephenson, the eminent engineer, made about the water-supply to Liverpool in 1850. The following is a brief abstract of the conclusions he arrived at:—

He considered that "the new red sandstone rock may be looked upon as almost equally permeable in every direction, and the whole mass regarded as a reservoir up to a certain level, to which, whenever wells are sunk, water will always be obtained, more or less abundantly."

The more the water is lowered by pumping below this level, the greater the quantity that will be obtained from the well, and the maximum quantity will be obtained where the water is lowered nearly to the bottom of the well, in which case the mass of rock which has been drained may be represented as an inverted cone. The bottom of the well being the apex of that cone, the sloping sides would represent the inclined surface of the water flowing towards the well in all directions. As the pumping is continued, the sides of the cone will become more and more obtuse, or, in other words, more nearly horizontal, until an inclination is established where the friction of the water, in moving through the pores and fissures of the rock, is in equilibrium with the gravity upon the plane. He further pointed out

that the area drained by a well might be represented by a circle of which the well was the centre, and that whether one well interfered with another or not depended on whether the drainage-circle of one well interfered with the drainage-circle of the other well. For instance, if we suppose that in Fig. 393 a well is sunk at A, it will drain an area represented by the circle B C D E. If another well is sunk at H, it will drain an area represented by the circle D I K L; and as these two circles do not touch one another, the wells A and H will not interfere with one another. If, on the other hand, a well is sunk at D, it will drain an area represented by the circle A F H G. This circle, it will be noticed, cuts both the other circles, and consequently the well at D will draw water from both the other wells. Mr. Stephenson considered that the radius of the circle in the case of the severe pumping at Liverpool was about one mile, so that no wells should be sunk nearer to one another than two miles; and he held that it was proved from the experience at Liverpool that in some cases wells affected each other even at greater distances than this.

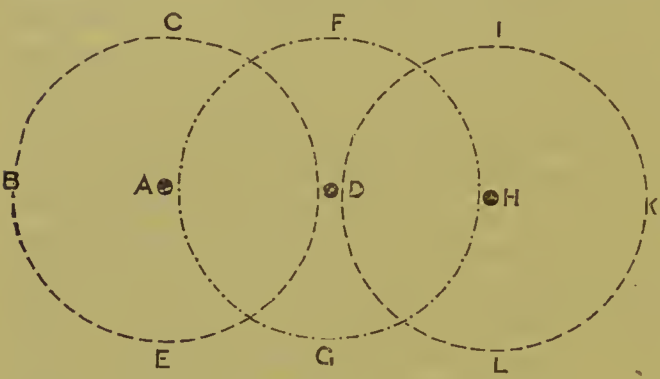

Fig. 393.

The later literature on the subject in England is little more than a repetition of Mr. Stephenson's conclusions. In his report no drawing is given of the inverted cone, but in subsequent writings sections are given, some of which, to say the least, are very misleading. The usual way in which the cone is represented is shown by the dotted lines A B and A C on Fig. 394.

On the Continent the question has been treated much more exhaustively. In the year 1863 M. Dupuit showed, from a theoretical consideration of the question, that the slope of the water towards the well must be represented by a *curved line* which became nearer and nearer horizontal as it receded from the well. Subsequently, actual measurements were made of this slope in Germany and elsewhere, which fully confirmed Dupuit's theoretical conclusions. In Fig. 394, the horizontal line H M L F represents the natural surface of the underground water, and the curved lines A D E F—A G H the slope taken by the water-surface when the water in the well is lowered to the point A by pumping, the vertical scale being purposely exaggerated so as to show the whole of the curve within a moderate compass. The actual slope, it will be seen, differs very materially from that usually shown in the English works on the subject, and some important results follow from the peculiar form of the curve. In the first place, it will be noticed that the effect of the curved incline is to make the influence of the well extend much farther than it would if the incline were straight, as usually represented. In the next place, the rapid rise of the curve near the well, followed by the gradual flattening afterwards, shows that the influence of pumping on the underground water decreases very rapidly at short distances from the well, but very slowly at long distances. Hence observations made in the neighbourhood of a well may lead to very erroneous conclusions. For instance, if the effect of pumping at A were observed on wells

situated at D and E, it would be found that the water in D was only lowered half as much as in A, and in E only a quarter as much as in A. From this it might be concluded that a little farther away than E the underground water would not be affected at all by the pumping at A, but the curve shows that this conclusion would be quite wrong.

If, without altering the depth of the well, less water is pumped from it, so that the water is only lowered to I instead of to A, the underground water will take the form shown by the curved lines I L, I M, and the influence of the pumping will only extend to L and M, instead of to F and H. From this it will be seen that what primarily governs the distance to which the influence of the pumping extends is not, as is often assumed, the depth of the well, but the extent to which the water in the well is depressed by the pumping. This distinction is an important one, as it is clear that a shallow well may draw much farther than a deep one if more water is pumped from the shallow well, so as to lower the water-surface to a greater extent than in the deep well.

As the distance to which the influence of the pumping extends depends so much on the depression due to the pumping, it is convenient to express this distance in terms of the depression, or, in other words, to say that the distance the well draws is twenty times the depression, thirty times the depression, and so on. How many times the depression this distance is, depends on the precise form of the curve, which varies greatly, accord-

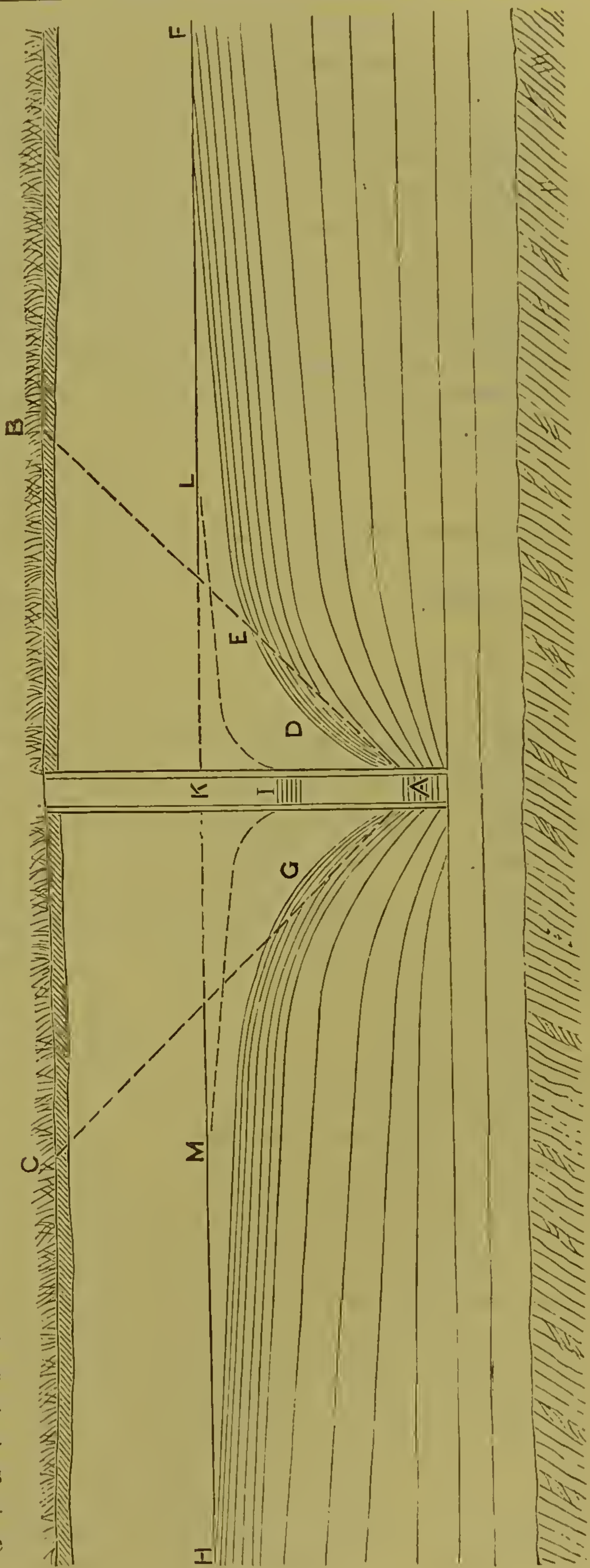

Fig. 394.

ing to the nature of the permeable strata in which the well is sunk. This distance is most important from a sanitary point of view, determining, as it does, not only whether one well will influence another, but whether or not a well will be polluted by a cesspool or other source of contamination in the neighbourhood; and we will therefore give a few examples of the distance under different circumstances. From what has been previously stated, it is evident that the only way to ascertain with precision the extreme distance from which a well draws is to sink a series of trial wells, or borings, at different distances from the well in question. We are not aware of any experiments of this kind which have been carried out in England, and we will therefore quote some of the results obtained by this method abroad, adding two observations in England, which from the circumstances under which they were made, appear to give nearly the true distance.

TABLE IV.

Locality.	Authority.	Nature of Strata.	Depression of Water in Well. Ft.	In.	Extreme distance to which Influence of Pumping extends. Feet.	Ratio of Distance to Depression.
Nuremberg, No. 1 Well	Herr A. Thiem	Fine Sand	0	7	23	39
			1	4	33	24
Nuremberg, No. 2 Well	Ditto	Ditto	1	2	23	20
			2	2	33	15
Dresden	Herr B. Salbach	Fine Gravel	8	2	180	22
Leipzig	Herr A. Thiem	Very Coarse Gravel	6	7	1,050	160
			20	3	1,378	68
Gravesend	Rev. J. Clutterbuck	Chalk	10	6	600	57
Liverpool	Mr. G. F. Deacon	New Red Sandstone	82	0	11,710	143

From Table IV. it will be seen that the distance to which the influence of pumping extends varies greatly in different cases, being in one case only fifteen times the depression, and in another as much as 160 times the depression. The chief circumstance which appears to influence the distance is the degree of permeability of the strata through which the water has to percolate. In fine sand and fine gravel, where there is a large amount of resistance to the passage of the water, the distance varies from fifteen to thirty-nine times the depression. In the chalk, where fissures exist which facilitate the passage of water, the distance is fifty-seven times the depression. In the very coarse gravel, where the water percolates freely, the distance is from sixty-eight to as much as 160 times the depression; and lastly, in the new red sandstone, where extensive fissures exist, affording a free passage for the water, the distance is 143 times the depression. In the next place, comparing the effect of different depressions in the same well, we see that the distance does not increase as rapidly as the depression. For instance, in well No. 1 at Nuremberg 7 inches depression gives 23 feet distance, and 1 foot 4 inches depression (or more than double), only gives 33 feet distance; and similar results will be seen in No. 2 well at Nuremburg, and in the Leipzig well. It follows, therefore,

that small depressions give a much greater distance in proportion to the amount of the depression than large ones do. This circumstance has an important bearing in the case of wells used for supplying private houses, as will be explained later on.

Before leaving the subject, it should be mentioned that for the sake of simplicity we have treated the natural underground water-surface as level, whereas in reality it almost always has more or less incline. The continental experiments, however, seem to show that the incline of the water-surface does not have so much influence as might be expected on the distance to which the well draws, so that the principles explained above will be found generally applicable in practice.

In applying the principles just explained to the case of wells supplying private houses, it might, at first sight, appear that the influence of the pumping in them cannot extend to any distance. The quantity of water drawn from such wells is comparatively small; and it might, therefore, be assumed that the depression of the water-level would be very small, and the distance to which the influence of the pumping extends also very small. This conclusion would, however, be erroneous. If the water is merely drawn from the well by a bucket, or pumped a few gallons at a time as required, the effect on the underground water will no doubt only be slight, but in houses of any size, when proper arrangements are made for water-supply, the case will be very different.

The water required for a house of any size will be pumped into a supply-tank, which will be filled, perhaps, only once a day, and the time occupied in pumping will be comparatively short, say an hour or so. The pumping, therefore, as long as it lasts, will be at a tolerably rapid rate, and the depression of the water-level in the well at the conclusion of the pumping will be often by no means small. Consequently the distance from which the well draws (which, as we have seen, depends on the depression) will also not be small. Even in cases where the depression is small, it must not hastily be assumed that the influence of the pumping only extends a small distance. One of the results arrived at from Table IV. was that this distance, though decreasing with the depression, did not decrease nearly so rapidly as the depression; and, consequently, small depressions may influence the underground water at comparatively long distances

CHAPTER LXXXI.

CONSTRUCTION OF WELLS AND EXAMPLES OF WATER-SUPPLY TO HOUSES.

Tube-wells—Method of Driving Tube-wells in Running Sand—Examples of Water-supply—Supply by Gravitation—Sand-filter—Hydraulic Ram—Pumping by Wind, Steam, or Gas Engine.

Wells are constructed in various ways, according to the depth to be sunk and the material to be excavated, and in some instances give rise to work requiring great skill and experience. In sinking wells through strata such as the new red sandstone, the chalk, or the oolites, it frequently happens that no lining is required, as the sides of the rock stand without any support; but in loose deposits, such as gravel, clay, and sand, the case is entirely altered, and recourse must be had to lining, or steining, as it is technically called. The most usual material for steining is brick, either laid dry or in cement. In some cases, however, where the work becomes difficult, iron cylinders are now very generally used. Again, where great depths have to be penetrated in search of water, boring is frequently resorted to.

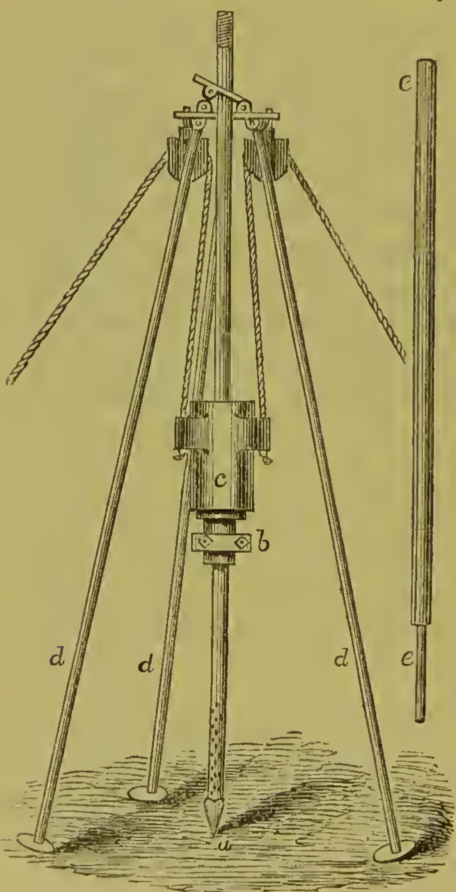

Fig. 395.

It would take too long to describe in detail the various methods adopted in sinking wells and executing borings. We will, therefore, confine ourselves to giving an account of a simple method which has been introduced in recent years, and has been found very useful for domestic water-supplies; we allude to the so-called tube-wells. The nature of these tube-wells has been generally described on page 789, and we will, therefore, at once proceed to give some practical details with reference to them.

The tubes used for tube-wells are of wrought iron, and usually $1\frac{1}{4}$ inch, 2 inches, and 3 inches internal diameter. The tube is perforated at the bottom for a length of 15 inches to 3 feet, with holes varying from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch. The lower end is furnished with a steel point, as shown at *a* in Fig. 395, and is slightly larger than the tube itself, the object of this being to make a passage-way for the sockets by which the tubes are connected.

The tubes are driven into the ground in a way similar to that adopted in pile-driving, but instead of the top of the tube receiving the blows, a clamp is screwed on the tube, as at (*b*) Fig. 395. The monkey, or driving-weight, *c*, slides upon the tube, which is set upright in the tripod (*d*, *d*, *d*,) and ropes from

the driving-weight are passed over pulleys in the top of the tripod. The driving-weight is now raised by pulling on the ropes on either side of the tube, and allowing the driving-weight to fall upon the clamp (*b*). When the tube has been driven so that the clamp (*b*) has reached the level of the ground, the driving-weight is held suspended, and the clamp is removed higher up the tube. The distance which it will be necessary to move the clamp will depend on the nature of the ground; if the ground be very hard, so as to require a greater fall of the driving-weight, the clamp should be raised only one foot; if, on the other hand, the ground is soft, so as to require only a small fall of the driving-weight, the clamp may be raised two feet. The driving is continued in this manner until the top of the tube has passed below the hole in the tripod-head, when a lengthening-bar (*e, e*) must be brought into use. The object of the lengthening-bar is to take the place of a new length of tube until the first tube has been driven completely into the ground, when the lengthening-bar can be removed, and the new length of tube screwed on. It would not do to screw the new length on before this, as the socket would be in the way of the working of the driving-weight.

During the operations, it is necessary to make frequent trials to test for the presence of water or accumulation of earth which may have forced itself through the perforations at the end of the tube. This is effected by lowering a hollow iron plummet within the tube, when the level of the water or of the earth may be ascertained, and in the case of earth, a small portion will be brought up on the under side of the plummet. If the earth within the tube has accumulated to more than one foot in depth, it must be removed by the cleaning-out tube specially provided for that purpose. When the accumulation within the tube is of a sandy nature, it may be best removed by the pump, water being first poured down the tube by means of a funnel.

After the water has been reached, the first thing to ascertain is the level at which it stands in the tube. If the water-level is within about 25 feet from the surface of the ground, the pump shown at Fig. 396 may be used. This pump, which is simply screwed upon the tube (see Fig. 397), is of special construction, having an enlarged top to facilitate the clearing-out of sand, and also a peculiar form of clack-valve (*a*). This valve has a tail-piece (*b*), so arranged that when the bucket (*c*) is forced down low enough it presses on the tail-piece, opens the valve, and allows the water in the pump-barrel suddenly to run back into the tube. This arrangement enables an operation to be performed which is of great importance to the success of a tube-well. The water is repeatedly drawn up, and then suddenly released, by which action the ground around the perforated end of the tube is loosened, and a space, or small reservoir, is created, allowing the water to percolate more freely to the tube. The water at first pumped will be more or less muddy and mixed with grit, but after continued pumping it becomes in most instances clear. Should sand, however, accumulate so fast as to prevent the pump from raising water, it will be necessary to put down the cleaning-out tube, and clear the well entirely of sand.

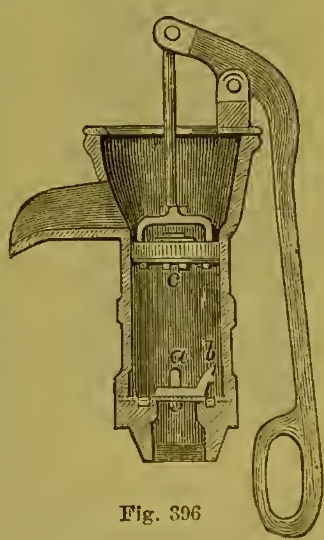

Fig. 396

It will readily be seen that tube-wells, in the majority of cases, would be superior to dug wells, which, from defective steining and leakage from surface-drainage, become very much polluted. It must not, however, hastily be concluded that contamination from all sources can be excluded in this way. For example, if the underground water generally is contaminated by cesspools in the manner shown on the diagram of Hincksey (page 822), it is evident that the mere fact of driving a tube-well, instead of sinking an ordinary well, would not enable a wholesome supply to be obtained.

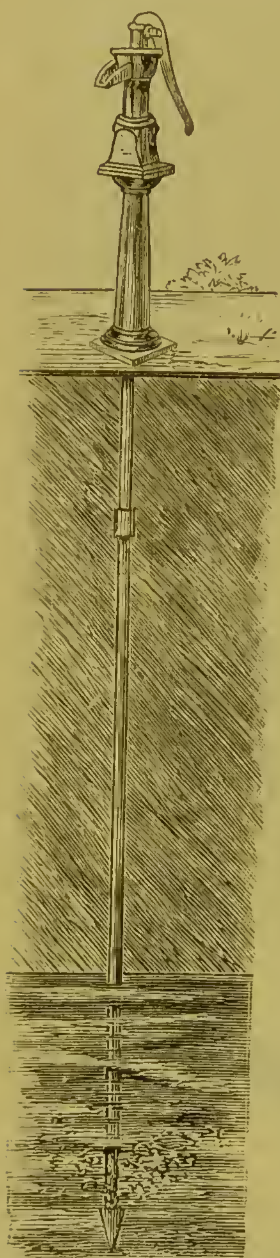

Fig. 397.

Although tube-wells are so useful in many cases, there are practical objections to their adoption in some instances. The fact of the water being drawn in through a comparatively small area at the lower end of the tube causes the water to enter the tube at a high velocity, and consequently sand, or other finely-divided material, is often carried into the tube and pumped up with the water, so as to render it unsuited for use. In some cases the water becomes clear after pumping for a considerable time, but in other cases this is not so; and unless the difficulty can be got over by special means, the water remains unfit for use.

Sand is one of the most troublesome soils to deal with in this respect, and various methods have been devised to exclude it from the tube. One method which has been adopted with success is to withdraw the tube, unscrew the point, and then drive the tube again. Sand is afterwards pumped out, until a considerable quantity has been raised, so as to form a cavity round the end of the tube. Into this cavity clean, sharp, grit gravel is introduced through the tube, and rammed down so as to fill up the cavity, as shown in Fig. 398. The open-ended tube is then withdrawn, and an ordinary pointed perforated tube drawn into the artificial bed of gravel formed in the cavity. In the blowing sand at Orpington, in Kent, a cavity could not be formed as in the last example, and recourse was therefore had to putting down a 7-inch tube in the ordinary manner, clearing the sand from within by the boring-shell. The 7-inch tubes, having reached the desired depth, were now gradually withdrawn, the space being filled in through the top of the tube with coarse gravel, forming a vertical gravel-bed, as on the diagram, Fig. 399,

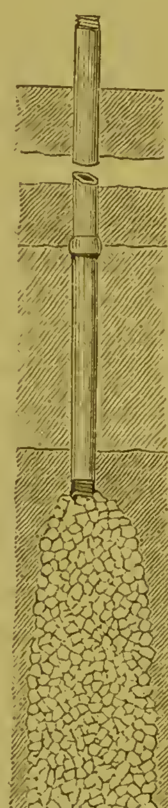

Fig. 398.

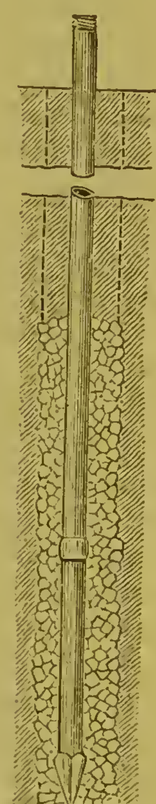

Fig. 399.

into which the ordinary pointed tube was driven. To prevent surface-drainage contaminating the well, clay was rammed tightly over the gravel.

If, on the other hand, the stratum penetrated, instead of being sand, is soft drift chalk, the difficulty is frequently very serious. The water pumped up has a milky appearance, caused by admixture of particles of chalk, which are so exceedingly fine that it is almost impossible to exclude them from the tube. The authors have known cases in which the water has been quite unusable from this cause. The difficulty would have been overcome in these cases by a dug well, the diameter of which would be twenty to thirty times greater than that of the tube-well, so that the area through which the water filters would be much greater than in the case of the tube-well. This would cause the velocity of entry to be greatly diminished, and the particles would consequently not be drawn in along with the water to any great extent. The dug well, moreover, would form a reservoir, or settling-tank, so that matters held in suspension would be deposited in the bottom of the well. In cases where the supply feeding the well is small, a dug well has the further great advantage of forming a reservoir, in which the water can gradually accumulate, ready to be raised when required for use.

EXAMPLES OF WATER-SUPPLY.

In order to supply a house satisfactorily, the water should be delivered to the highest parts of the building. In many cases a source of supply may be discovered at a sufficient height to deliver the water by gravitation, but in other cases the

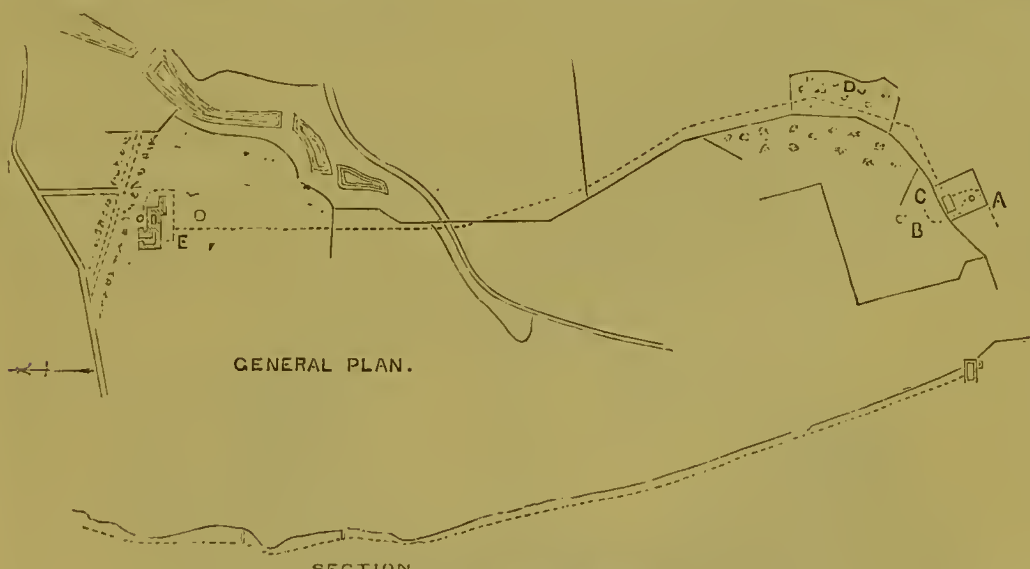

Fig. 400.—Country Mansion.

water must be raised either by utilising the power of a stream or of the wind, or by adopting some special means, such as a steam-engine, gas-engine, horse-power, or hand-power.

Whether the supply is by gravitation or by pumping, the most desirable arrangement, where it can be adopted, is to construct a reservoir at a sufficiently high level to command the highest parts of the house. Where, however, the house

is situated on high ground, a reservoir is often not practicable, and in such cases a water-tower may be adopted with advantage—that is to say, a tower upon which a tank is placed. Where the cost of a water-tower cannot be incurred, it is usual to

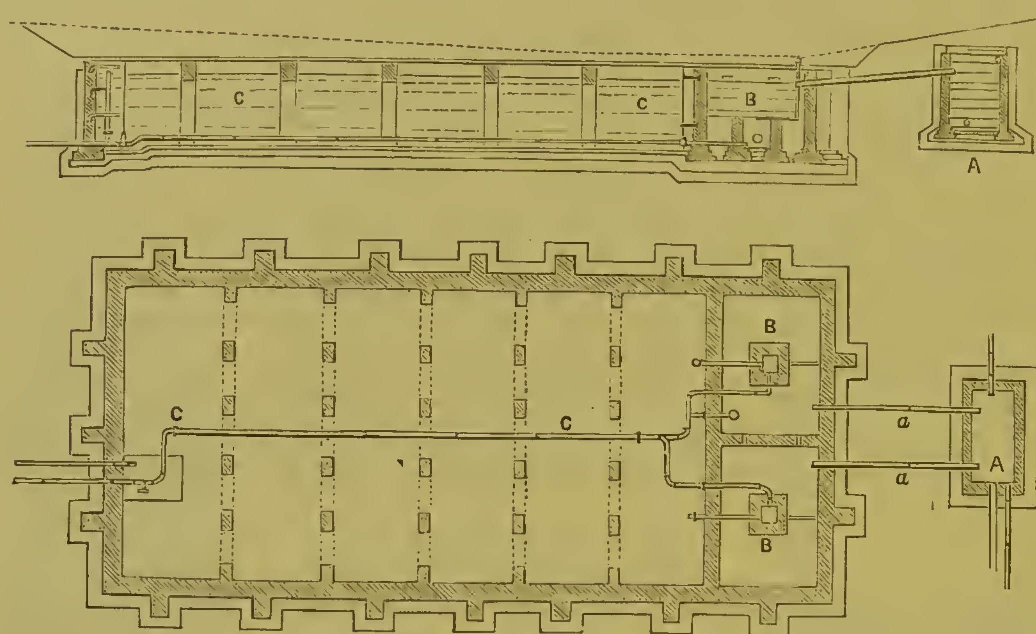

Fig 401.

place the tank in the roof of the house; but although this arrangement may give a good supply to the house, it is by no means so satisfactory as a water-tower in cases where a fire-service has to be provided.

As an example of a water-supply by gravitation, we give in Figs. 400, 401, and 402 the particulars of the method adopted for a mansion in Lincolnshire, for which we are indebted to the kindness of Mr. William Eassie, C.E.

The supply was obtained from springs in the lower oolite, situated at A and B, Fig. 400, which gives a general plan and section of the works. The springs were at

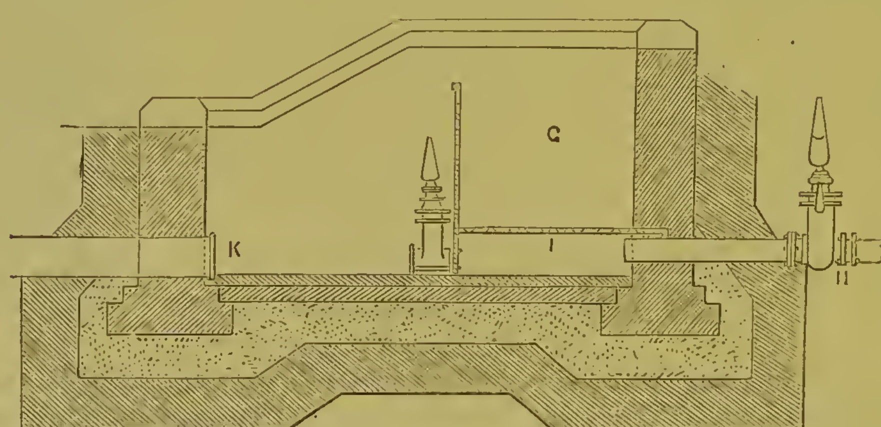

Fig. 402.—Sand-washer.

a considerable elevation, so that it was possible to take the supply by gravitation, and thus avoid pumping. A brick chamber, C, was constructed to receive the springs, spring B being conducted into it by an iron pipe under the brook, and

spring A by an earthenware pipe. The filters and service reservoir were also constructed at the point marked C on the plan.

These works are shown in detail at Fig. 401, which is a plan and section showing the filters B B in duplicate, and the covered reservoir, C C. These portions of the work are constructed of brickwork in cement, and have an outer lining of clay puddle, in order to make them thoroughly water-tight. The water from the springs passes into the chamber A, from which it is led by the pipe (a) into either of the filters, B B, and after being filtered it passes down into the reservoir, C C. The filters are furnished with clean sharp sand and gravel eighteen inches thick, and a top bed of eighteen inches of clean-washed sand. Near the filters is placed a sand-washer (Fig. 402), for cleaning the filtering-material. The gravel and sand to be washed is put into the perforated iron receptacle, G. The water from the iron pipe which conveys spring B (Fig. 400) is brought by the pipe H under the perforated bottom (I) of the iron receptacle, and passes upwards through the perforations, thus thoroughly washing the filtering-material. The muddy water from this process escapes by the earthenware pipe K into a ditch. The reservoir is covered over with stone slabs on iron girders, and has suitable manholes for access. Bell-mouthed overflows, six inches diameter, are also provided for the reservoir and filters.

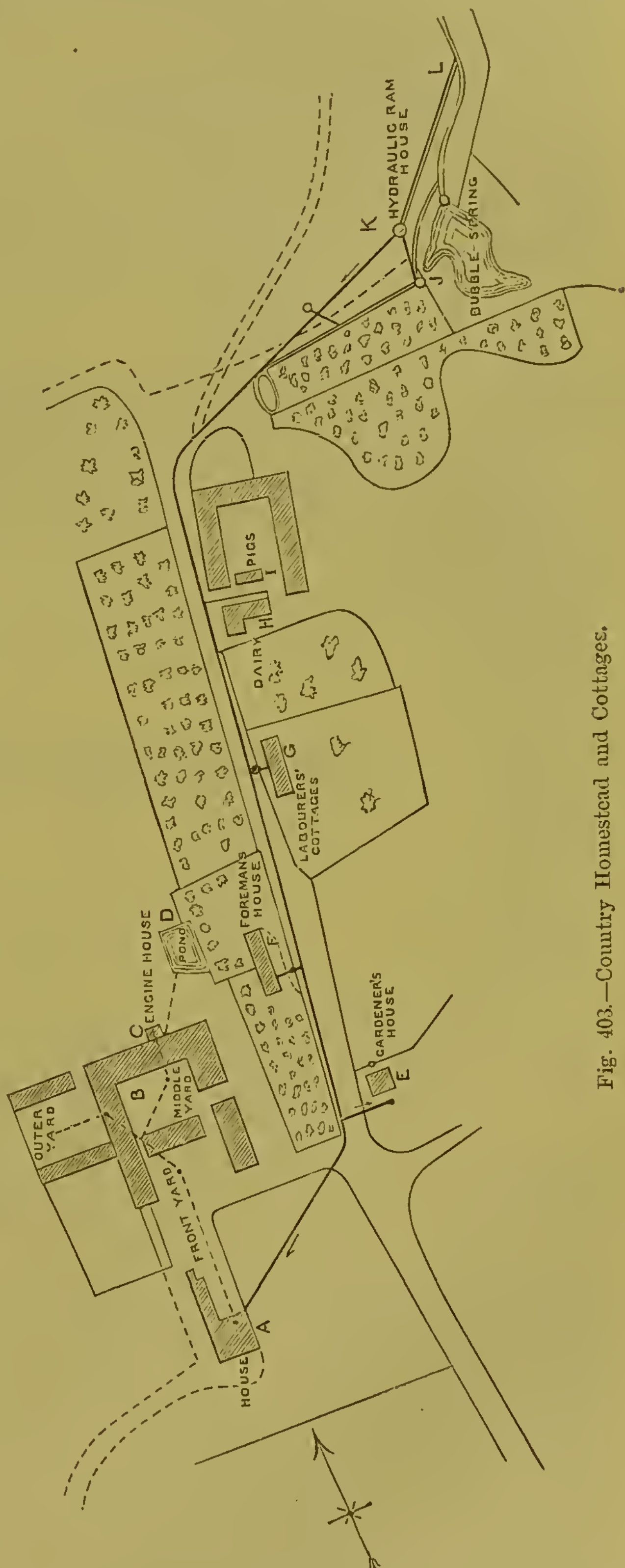

Fig. 403.—Country Homestead and Cottages.

From the reservoir the water is taken by an iron main, C D E (Fig. 400), and then branches off to supply the various parts of the mansion. This main is laid at an average depth of 2 feet 6 inches, and provision is made by a number of hydrants for delivering

water in case of fire, the pressure being sufficient to force it to all parts of the building. The hydraulic lifts in the establishment are also worked by the pressure of water direct from the main.

We will now give an example where the water was raised by a hydraulic ram. The case selected is a peculiarly interesting one, as the supply was derived from an artesian boring, which yielded water enough not only to supply a farm homestead and cottages, but also to work the hydraulic ram, which forced the water to the required height. The farm homestead itself, which is near Dorchester, is situated on high ground at the junction of the plastic clay and chalk, and the artesian boring

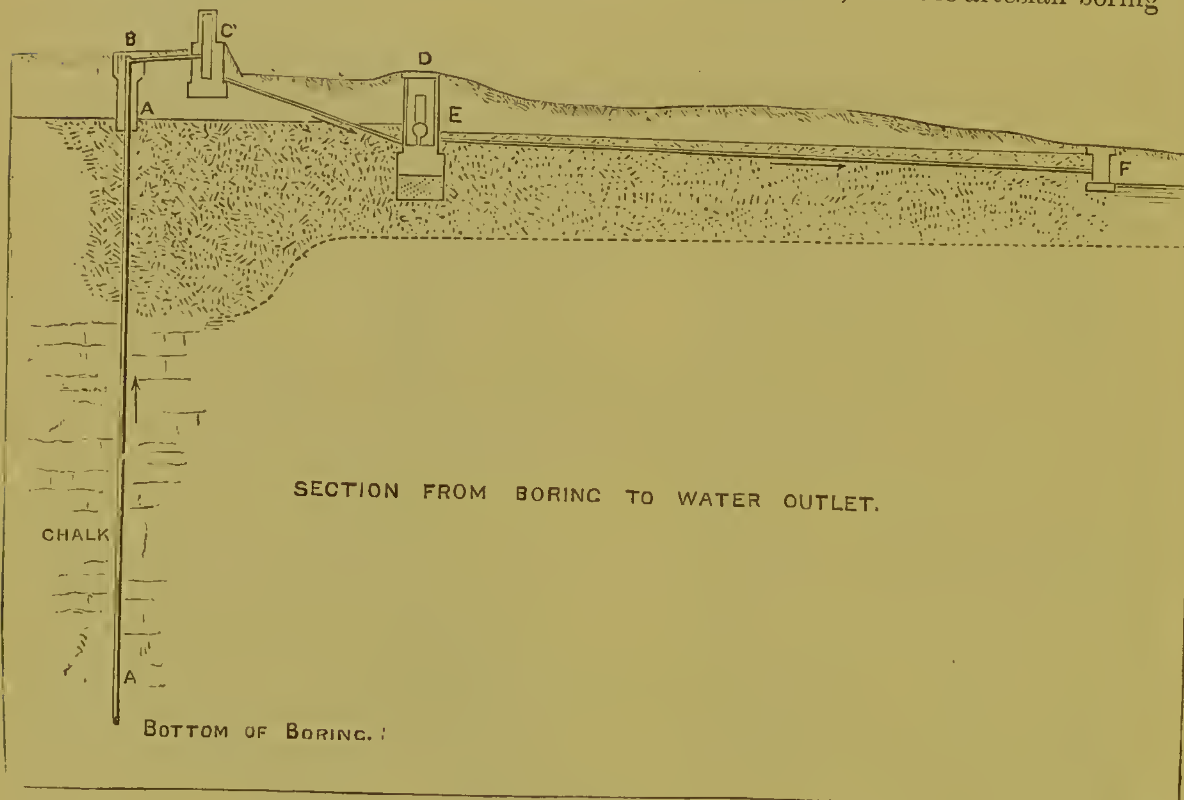

Fig. 404.

is at a lower level, where the chalk dips underneath the plastic clay. Figs. 403, 404, 405, 406 give the particulars of the works, which were designed and carried out by one of the authors (Mr. Rogers Field.)

Fig. 403 is a general plan, of which A is the farm-house, B the farm-building, J the artesian boring, and K the hydraulic ram. The artesian boring was driven to a depth of nearly fifty feet through the plastic clay formation into the chalk, and the water rose about six feet above the surface. As the fall which was available for working the ram was very slight, advantage was taken of the rise of the water above the ground to give additional fall, but even then the available fall for working the ram was only 7 feet. From the ram, K, the water is forced through a $1\frac{1}{4}$-inch wrought-iron main, K F A, to a cistern at the top of the farm-house, A, the total lift from the ram to the cistern being 70 feet. The wrought-iron main is protected from rust by the Barff process. The main on its way to the farm-house supplies the dairy and buildings at H, the labourers' cottages at G, the foreman's house at F.

and the gardener's house at E. The overflow from the cistern in the farm-house is taken by a 1-inch barffed wrought-iron pipe (A B) to various drinking-troughs, after which the overflow passes by a drain-pipe to a tank under the engine-house, C, and finally into the pond, D.

Fig. 404 is a section, showing the relative positions of the bore-tube and hydraulic ram. The water from the artesian boring, A A, rises through the pipe A B C into the collecting-chamber C, from which it flows to the hydraulic ram D. The waste from the hydraulic ram is carried through the drain E F into a ditch at F. Fig. 405 is a detail, showing the special cast-iron bend fixed on the top of the bore-pipe to conduct the water into the straining-chamber. A is the bore-tube, and B a movable cap which answers the double purpose of affording direct access to the bore-tube and of diverting the water from the collecting-chamber and the ram, should this be required for repairs or any other reason. When this cap is removed, the water from the bore-tube will escape at B into a channel constructed in concrete,

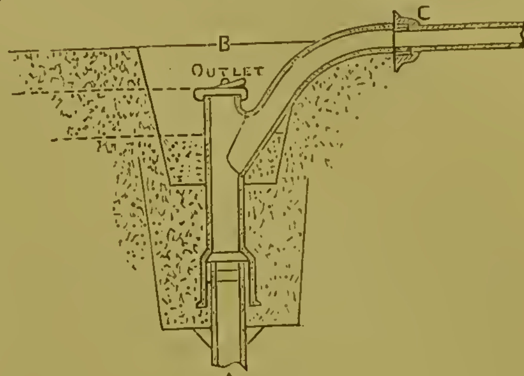

Fig. 405.

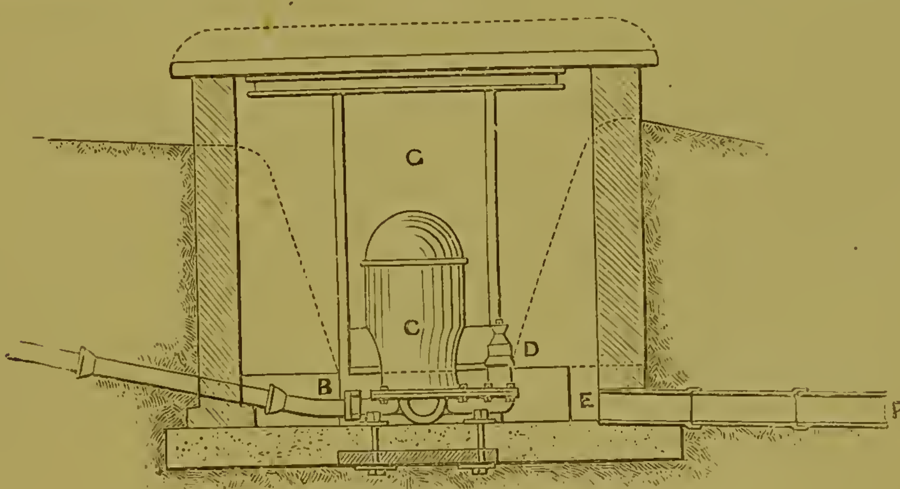

Fig. 406.—Hydraulic Ram.

which conveys it away into a ditch. Fig. 406 is a detail of the hydraulic ram and house. A B is the cast-iron pipe bringing the water from the collecting-chamber to the hydraulic ram, C D. D is the escape-valve, and C is the air-vessel from which the $1\frac{1}{4}$-inch rising main is led to the farm-house. E F is the drain which takes the overflow from the ram. It will be noticed that the ram is placed in a suitable brick chamber partly sunk into the ground, and approached by the door G.

The quantity of water delivered to the house and buildings is 800 to 1,000 gallons per diem. As the buildings E F G H are supplied directly by the rising main, special means had to be adopted to give a sufficient quantity of water, and yet prevent waste, which would have interfered with the supply to the house. The amount pumped by the ram was insufficient to supply a sudden demand, and storage had

therefore to be provided, as it would not do to use the cistern in the house. This storage was effected in a simple way, by fixing a closed iron cylinder on the course of the rising main in the ground floor of the farm-house. The taps for drawing water at the cottages were provided with a waste-preventing arrangement, so that only a pailful of water could be drawn at one time. This prevented any tap being left running, which would have stopped the ram from forcing water to the farm-house.

It frequently happens that the water-power is afforded by a stream which is not of suitable quality for supplying a house. In such cases an ordinary hydraulic ram like that described above could not of course be used, and although there is a form of hydraulic ram constructed which will raise water other than that which works it, the most convenient and reliable arrangement is generally to let the stream drive a water-wheel or turbine, which will work pumps for forcing the pure water to the house from a small spring.

In cases where no water-power is available recourse is sometimes had to wind-power, which has the great advantage of costing very little. Wind-engines are not often used in this country, but in America they have been largely employed. The chief drawback in depending on this power is of course that there are every now and then intervals of several days in succession, when the wind is not sufficient to work the pumps attached to the wind-engine. It is therefore essential to have a tank or reservoir of sufficient capacity to hold a supply for use for the longest intervals during which the pumps will not work—perhaps a fortnight or more. If there is high ground near the house on which a reservoir can be constructed, wind-power can be adopted with economy; but if there is no such high ground, the construction of an elevated water-tank of sufficient capacity would generally be so costly as to negative the employment of a wind-engine.

In numerous cases recourse must be had to a more costly kind of power, such as that of the steam-engine. We cannot here enter into the relative advantages of these various machines, but may state generally that where there is other work to do besides pumping (such as driving machinery for a laundry, sawing wood, etc.), a steam-engine will probably be advantageous; but where there is only pumping to be done a gas-engine or hot-air engine will be found convenient and economical.

THE NURSERY.

By William Squire, M.D., F.R.C.P., etc.

CHAPTER LXXXII.

Introductory—Health of Children the Measure of a Healthy Home—Main Wants of the Nursery the same in all Grades of Society.

The right to be healthy should be considered as much the inheritance of every member of a civilised community as the right to be free. At length this right is advocated with something of the care, study, and energy expended in acquiring political and religious liberties. The truest individual freedom is found in subservience to law. Health comes from obedience to the sanitary laws which science traces in relation to ourselves. It is the interest of the whole community to apply the principles of sanitary law to the circumstances under which it lives.

The foregoing pages will have shown how extensive and varied are the means that may be requisite to maintain the health and comfort of large numbers of people associated, as is now more and more the rule of our social state. At first sight the appliances required seem to imply a great increase of general wealth, or immense strides by all towards social equality. This is not so; the objects aimed at are independent of class distinctions, and within reach of the poorest, while often far removed from the rich; however much the material circumstances of private life may vary, the same care is needed to see that common articles of food should be pure, while fresh air and cleanliness may be attained by all. Moreover, economy results from co-operation towards a common purpose. Water is supplied to a number of houses at less expense than when separately fetched by the inmates of each dwelling; at the same time refuse is removed from them, and sufficiency of light and air secured at a moderate rate.

Sanitary defects in dwellings are most plainly shown in spoiling the health of children; the young soonest suffer from bad air, noxious vapours, damp, dust, and want of cleanliness. Into houses where the children are lively and well we may be sure no sewer-gas enters; this may not be the particular cause of illness where children are sickly, but some violation of sanitary law will be found that checks healthy development. Nowhere is the right of health to be more vigorously maintained, or more jealously guarded, than in the nursery; for while the neglect of sanitation here saps the cheerfulness of childhood, and ruins the fair prospect of youth, nowhere is attention to sanitary law more promptly and permanently rewarded than in the normal evolution of all we hope for in the young. Throughout this article the healthy condition of the child, and the means of ascertaining it, will be set forth as the measure of how far the nursery is made healthy.

The details of nursery fittings must vary extremely in the different grades of society, while many of the same details of nursery management can be commonly carried out; the principles to be kept in view are the same in all stations of life,

and may often be as well observed in the poorest as in the richest dwellings. No amount of grandeur will keep mansions free from noxious gases; the most costly chamber soon becomes unhealthy if constantly occupied. Luxury can add nothing to the pure milk required by infants; when this has to be supplemented, the same care must be taken that the added food should be fresh and uncontaminated, a care required earlier and oftener among the rich than among the poor. Arrest of nutrition, actual starvation, from dieting an infant on what it cannot assimilate, is still frequent among all classes. Danger from placing a baby in the horizontal position the moment it has finished a full meal, or of covering its face completely during sleep, may happen on a bed of down. Sleep may be prevented by tight bands, or miserable swathes, in a satin basinette or gilded cradle. Warmth can be kept by plain clothes or loose wraps, while all the evils of chill may be suffered in the embroidered dress of fashion.

> "If onely to go warme were gorgeous,
> Why Nature needs not what thou gorgeous wear'st,
> Which scarcely keepes thee warme."
>
> *King Lear*, Act II., sc. 4.

Children thrive best with free and frequent access to the outer air; no attempt should be made to render any suite of apartments for the young independent of this, and any arrangement that makes it difficult for children to get out of doors is to be avoided. The infant schools for the poor in large towns are distinctly useful in bringing young children from the rooms they occupy at home into the fresh air twice a day. All schoolrooms are now improved. Thirty years ago some class-rooms in our highest schools were inferior to any since permitted to the poor. The author of "Seven Years at Eton" says (p. 47), "There was one musty little place under the colonnade where seventy boys used to be packed, but which was so dark and stuffy that the door had to be left open in all weathers. Another dreadful little room was a narrow loft with about a dozen tiers of seats, the uppermost being so high that the boys seated on it could touch the ceiling. The forms were so low and so close to each other that boys sat with their knees higher than their waists; and the boys in each row rested their backs against the knees of those in the row behind." No harm resulted, for the lesson seldom exceeded half an hour. Longer hours in a cramped position will cause spinal curvature in the young, and bad light in reading and writing continued for any time, produces the short-sightedness so frequently met with.

In small houses, while the family is small, the best rooms are very properly used as nurseries; the nursing is good, for it is directly under the mother's eye. Here some of the common cares and duties that make a good nurse are practically taught. The simple precautions thus learned are not always attended to when the nurse acts independently of the mother. Old custom lingers long in nursery matters, longest perhaps in the first traditional handling of infants, where the experience of the nurse has to be trusted to. The most "experienced nurse" has to be distrusted; experience is often pleaded as an excuse for carelessness, or is a cause for the nurse's convenience coming before the welfare of the child. To some nurses it is too much trouble to use a thermometer for the infant's bath, they can tell if it is the right heat: if not, it has been said, the infant will cry and look red if the water be too hot, blue if too

cold. They are slow also to consult the thermometer on the wall; they like the room to be warm, and prefer a bright light from gas or lamps when the night-light is all that should be allowed. In a large establishment the arrangement of the rooms set apart for the nurseries should be such, that while adapted to the comfort of the child, they should be so near those of the mother to be almost part of them, and easily visited by her at any time either of the day or night.

Our first notions of home start from the nursery. Here, when all the wants of early life are met, healthy development soon leads to conscious comfort. The youngest child has this happy knowledge. Rooted in the nursery, it grows and gains upon us there. Children come to feel that food, rest, quiet, and pleasant ease belong to the place to which they are always brought back after all the changes that excite or tire, where some one shows them care and love, and the greeting of another self is sure. This kindly attention, with all around orderly, clean, and cheerful, not only makes childhood happy, but leads to strength, good nature, trust, courage, and virtue.

Houses may be built without nurseries, though without them they can hardly be made homes. Every house should have some quiet, cheerful room apart, such as might be a delightful retreat from the busy part of indoor life, undisturbed by noises from without. A double door easily fits this to the requirements of a day-room for children; then noises from within, necessary to active childhood, need not interfere with the comfort of inmates or visitors. This room should have a sunny aspect, with large low windows, a cheerful prospect, and possibly a separate entrance, or ready means of going out of doors. The bed-rooms, near together and near to the chief family room, should make a system of their own, with clothes-room or nurse's room, dressing-room, bath-room, and closet or scullery attached; the one part of this system readily associates itself with the principal bed-rooms of the house, the other with the department of the housekeeper or other domestics; a separate staircase is always a convenience, and, if for children, should have steps broader and lower than are usual. Some of these rooms can be readily shut off if not required.

Such elements of comfort and completeness in a house are always serviceable; no better accommodation could be offered to friends or visitors than what is designed for the most cherished members of a family. If happily peopled by children, this part of home becomes to them the dearest spot on earth. It may afterwards be the delight of children's children, the rallying-point or centre of a family, that shall attract its many members and hold them together, knitting the generations each to each. The gradual transformation of the play-room into the study, or the dressing-room into the boudoir, almost like a part of individual evolution, preserves a continuity of association that becomes one of the most treasured possessions of the inmates.

CHAPTER LXXXIII.

The Young much Indoors—Large Proportion of Time required for Rest—Bed-room Conservancy—Pure Air—Sleep—Infant Physiology and Hygiene.

Children are the better for frequent changes of room; they have to spend most of their time in the house; they require short intervals between their meals, with quick transitions from play to rest. The meals should be taken where there is no litter of toys; a quiet room is needed both for work and sleep. Means of getting change of air, and of taking exercise within-doors or under cover, are essential. In town houses of moderate size, the best place for welcome change is the drawing-room; it is often the largest room, and the infant may well spend some time there; all the children, under supervision, may be familiar visitors.

Home life to the younger members of a family and to the gentler sex means that by far the largest part of every day must be spent indoors, and half of it—at least for the very young—in the bed-room. No attempt should ever be made to rear children in a single room. The necessity of providing a full supply of pure and fresh air in youth, when change and growth are most active, is obvious. Whatever has been said of the general requirements of a house, it is in the nursery where all that is most essential to health and comfort should be most perfectly represented. The active man, whose duties for the greater part of the day call him abroad, sooner forgets his fatigue, and has his strength for renewed activity more thoroughly restored, where a healthy home awaits his return. For those who have to spend most of their time within, from duty or necessity, the greatest care in all the details of a wholesome dwelling are most wanted. The strong man after free respiration out of doors may pass through foul or damp air in the basement of the house with the inner breath of his capacious chest untouched; he may sit in a close hot parlour without enervation, or sleep in a chilled bed-room without his vigorous circulation being seriously depressed. Not so those who stay at home; from these evils even the strong would suffer; delicate women, susceptible youth, tender childhood suffer most. The mature and robust bear cold well, so that the air be dry and pure; the young must have warmth. Another necessity for those much indoors is light. No room can be healthy, however well calculated for its inmates, unless, in addition to the requisite air-space, the air it contains is being constantly renewed; this is ventilation. Most important of all those requirements is cleanliness.

The cares exercised for a healthy person kept in bed by an accident, or for an invalid confined to the house or room for a season, set forth what infants and children want. At first the comfort of the bed room is everything; the night is not all rest, and part of the day has to be shaded into night. Soon it becomes possible to change the room for a time; then, open the windows, brush the floor, dust and clean the chamber, so as to replenish it with pure air, and remove the myriad particles ever spoiling the oxygen of its freshness. While the room is still occupied much of this can be done; done quickly, that the temperature be not lowered unduly, and so done as not to expose the patient to chill. The air of the room

must be changed, to some extent, both in the day and at night; a partly-open door or window only admits fresh air to some part of the room, but if not to the part of the room occupied, or even to the very face of the occupant, the breath is breathed over again, and effete matters or injurious emanations mingle with the vital air. A special atmosphere, readily vitiated, forms around a cot or within the curtains of a bed; this may be liked for its warmth, and even be useful on that account, but this inner air must not be kept without movement; besides the storms of room-cleaning, some gentle fanning should from time to time disturb its quiet. The lowest layers of air about or under a bed, or by the cot near it, become soonest impure; respired vapour is heavy, and contains moisture, with numerous particles that settle in it, contaminating the lower stratum of air even when nothing is left near the bed that should be removed. Have no receptacle for fluid close by; keep no clothes or boxes near the bed; have no obstructing valences; and see that the floor is clear underneath.

What is right for the sick-room is right for all sleeping-rooms, and of greatest moment in the room where a child is born. The axiom, "what is good for the mother is good for the child," is most applicable here. The mother's room is the child's first nursery; any separate apartment, whether with fire for toilet purposes, as a vestibule, or a more quiet recess for the cradle, must practically be part of the mother's room as to temperature and ventilation.

Pure air, warmth, repose are needed by both mother and child. A few words may here be said on each of these necessities as regards the child. Air to breathe provides for the first great want of every independent organism, so maintaining the common gift to every living creature—the breath of life. Warmth, a product of every living body, is only favoured and preserved by the state of the surrounding medium, not produced by it; food must supply the material for nutritive changes within the body that produce heat, while growth and development in special structure and function proceed. In the higher forms of life, where conscious energy is evolved, the alternation of sleep becomes a necessity; simple forms in the lower stages of existence may slowly vegetate or grow with no other changes of activity than such as come with the varying degrees of heat and light or the conditions of the medium in which they live. Our more complex bodies, endowed with warm blood and organised for this vital current moving into direct and constantly-renewed contact with the air, start at the instant of birth into such activity of function, such conscious sense of change, that, but for the repose sleep brings to the store-centres of energy, exhaustion following effort would weaken the delicate structure on which all vital actions depend, and impair, instead of aiding, growth and strength.

Some facts and observations on infant physiology will help to explain in what degree and manner sleep, warmth, food, and exercise are necessary to the well-being of a new-born child, and tend to the maintenance of health in childhood. No point in human physiology is more remarkable than the uniformity of temperature preserved by the body in health from the earliest infancy to extreme old age—literally, from the cradle to the grave—even under the most opposite external conditions of heat and cold. Many causes may more readily depress our body-heat at the extremes of life, and the young require to be carefully guarded from much variation of external temperature in either direction. It is obvious that in relation

to surrounding cold, the smaller the warm body the sooner must its heat be abstracted; it is found that exposure to extremes of heat sooner overpowers the heat-regulating processes in the young, but it remains a wonder how all human beings, in any climate, at every period of life, preserve one even body-temperature. We know that the warmth of some animals at certain periods, as during hybernation, and under some eonditions, varies somewhat; it is maintained above that of the medium around in all. One condition of healthy action of our bodies is that the temperature should be nearly uniform, always near 98°·5 or 99° Fahr., just 37° Cent.; it may be one degree lower during sleep, or half a degree higher during great activity of function. This heat is kept up by the molecular change in the tissue accompanying nutrition, secretion, and waste effected by the oxygen carried in the blood, together with nutrient material in every part under the influence and even control of its innervation. Heat is lost by direct cooling of the blood as it circulates in the vessels of the skin and of the lungs; some is carried away in excretions; much is set free by the moisture given off both by the cutaneous and pulmonary surfaces; evaporation always cools.

An example of the complex and delicate reaction of the whole heat-regulating machinery of our bodies is seen in the sensitiveness of the skin to cold. Under this stimulus the cutaneous vessels contract, allowing less blood to enter, so that the loss of heat by the surface is checked; at the same time more blood is sent to the interior of the body with conservation of heat. Not only cold from without, but irritation from within (often such as interferes with heat-production), also sets in action the same heat-regulating mechanism; a reflex influence on the vaso-motor nerves of the skin causes pallor, or coolness of surface, or in a further degree makes what is called goose-skin.

Under a different stimulus the cutaneous vessels relax, perspiration pours forth, and the interior of the body loses heat. To man as a denizen of sub-tropical climates this degree of warmth is natural; amidst perfectly congenial surroundings the primary sensation would not strongly urge his intelligence to expedients useful against heat, rain, wind, and cold. No place can be always free from those changes, and a wider experience would soon enforce the necessity of some provision against them. Shelter, fire, and clothing are the earliest conquests of humanity, the object being warmth; to keep oneself warm is cited as a proof of innate or mother wit in its rudimentary form. To long and constant success in this effort the equable body-heat of our race may be due, and this capacity for keeping up an even temperature is not unconnected with the progress of communities, the growth of social manners, and the capability of sustained powers of will and thought.

An infant no sooner breathes than the heat of the body attains the normal; the first differences of warm or cold felt by the skin, the first sense of touch, excite the requisite movements to bring air into contact with the newly-diverted blood current, and life goes on at full rate. Respiration is aided by a child's first exertion in crying; washing and rubbing also afford an exercise beyond the muscular kicks and struggles excited; all these quicken change and tend to develop heat. Let suitable covering retain this warmth at the surface, sleep will then be quiet and prolonged. A healthy child born at term has a reserve supply of material to keep up the body-heat, so that a little liquid only, at long intervals, is all the food required for the first day or two, and that little can mostly be supplied by the

mother. The right time for this supply of food is after sleep. Sleep is interrupted by a sense of want as well as by other discomforts; those obviated, as by change of position or of articles of clothing, or by warmth, sleep returns. Sometimes a tight band or a scratch may have disturbed, or there may be fulness from flatulence after food, or distension from over-feeding, or heat, or thirst; so that if food has recently been given, instead of offering more, search first for the possible cause of unrest; lighter covering or a tea-spoonful of cold water may be all that is required. But if this sense of want underlies the discomfort, or has become an urgent element of it, no conciliation is possible without the supply of food.

During perfectly undisturbed slumber, while motion and sensation are at rest, secretion and nutrition are active, repair goes on, waste is less, and the temperature of the body is slightly lowered. This lowering is more marked in profound sleep, or if sleep be prolonged. Under the stimulus of food the child's temperature is at once restored; give only a small quantity of food, two or three ounces of liquid one degree above the child's body-heat, and the whole body will be raised half a degree in temperature, an increase twenty-fold that of the heat supplied. Milk and water, taken nearly cold or several degrees below the child's temperature, will determine a similar rise more slowly produced. No infant will take hot food; a careless nurse may place in a bottle for a child liquid as hot as the tea she drinks, but, saved from scalding by the elastic tube with which most infants' bottles are provided, the child, however hungry, will not draw it up until the temperature has fallen to 110° Fahr., or what would be considered barely tepid, if not quite cold, by a tea-drinker. A full meal of some of the more stimulating artificial infants' food, or even a full natural meal, will sometimes flush the head and face, and rouse the heat-regulating reaction; the vessels of the skin fill, and free perspiration dissipates any excess of heat-production. To allow of easy escape of any flatulence in the stomach, a child should be held up or a little forward for a short time after a meal. Nor is this the time for replacing the infant in a heated bed or cot, but rather for change of covering, or a complete undressing for sponging the whole surface of the body. The regular morning bath is better given a little time after a slight meal than immediately after a full one. The water should only be tepid; after free ablution the use of water a little colder than the bath provokes a reaction that reddens the skin, and, instead of lowering the temperature of the body, tends to equalise it by exciting on the surface a degree of warm already existing within.

The surface temperature soon after birth has been found higher than that of the interior of the body; this shows the care necessary to guard the tender skin from rough handling or over-stimulation. Continued excitation or undue reaction would tend to exhaustion without rest and sleep.

These physiological commentaries, if only indirectly applicable to the nursery, embody principles very generally attended to by the nurse; they indicate many points of nursery management and some of the provisions necessary for the nursery. Healthy balance of action is aided by external dry warmth and the intermitting stimulus of light. The child should be dressed and undressed before a fire, or, in summer, in sunlight. A blaze from the hearth is a cheery substitute for sunshine; it is grateful to other senses than that of sight, and makes thorough exposure of every part of the body for cleanliness and comfort, not only safe and wholesome, but pleasant. At first the infant has better care in close proximity to the mother's

room than is possible in the nursery for other children; they would disturb the new-comer in the day, and in their turn be disturbed at night. Night is not the only season of repose for young infants; sleep comes to them as readily in the day as in the night, and their food is often as easily obtained in the night as in the day. Not many revolutions of the earth bring

> "Labour and rest, as day and night to men
> Successive, and the timely dew of sleep
> Now falling with soft slumbrous weight inclines
> Our eyelids; other Creatures all day long
> Rove idle unimploid, and less need rest;
> Man hath his daily work of body or mind
> Appointed, which declares his Dignitie,
> And the regard of Heav'n on all his waies;
> While other Animals unactive range,
> And of their doings God takes no account."
>
> *Paradise Lost*, Bk. IV., lines 613—622.

Some harmony of this rhythm undulates into our being, and habit soon begins to play its part in favouring the hours of sleep.

An important part of education is to fix useful habits, and it is one that cannot be commenced too soon. Sleep—tired nature's sweet restorer—is as essential to the building up of the body and the acquirement of the complex nervous organisation in man as it is to the repair of waste or to the restoration of energy. A mobility of nervous functions, to which many of the dangers incidental to infantile life are due, most marked in the earlier months of life, is prolonged or intensified by want of sleep. This gives rise to great trouble at the moment, and to after anxiety from persistent neurotic disturbance. A large share of undisturbed slumber has to be secured for infants, some of which must come in the day; for this purpose the place for repose must be shielded from light as well as from noise. Too much light can hardly be admitted to children's day-rooms, but the sleeping-room must be shaded from the direct sun by blinds or shutters, and the beds so arranged as not to face the early sunlight. The only means of making darkness visible to be allowed in the bed-room at night are a shaded candle or night-lights; of the latter, those that burn ten hours in the winter and six or eight in the summer do very well with a covered vessel over, where some water, barley water, or cocoa can be kept warm to use with fresh milk, if food is wanted in the night. All spirit-lamps are dangerous; the solid-flame adaptations to various cooking-tins are only for exceptional purposes, and entail risks of accidental upset.

As a matter of habit, it is important not to be late in getting an infant to sleep, nor to choose the night hours for a full meal. The child should be dressed at the same early hour every evening; the last meal can be taken comfortably after the bath, some time before sleep. After the chief morning meal, which follows the bath or dressing, is a good time for a child to sleep. Nor does the sleep out of doors, soon induced, prevent sound slumber on coming in, after the further fatigue of change of dress and the satisfaction of the mid-day meal. Young children wake early in the morning, and are quite ready for a nap after breakfast as well as after dinner. These two periods of the day may well be chosen for favouring a

regular time for rest; either may be selected for habitual continuance for a year or so after the child leaves its first nursery. In this garden of Eden, where the chief wants of food and warmth are provided for, the child will grow and flourish; but, instead of always staying in this paradise, it must be carried into the outer world for the mild excitement of changed surroundings, and for the double necessity of breathing fresh air and of admitting new air to the room last occupied.

Children sometimes suffer fatigue or chill from the way in which they are first dressed in the morning; they require a biscuit or some milk as soon as they get up, and before the ablutions begin; it is much better to give them a general wash in warmed water, in which they could stand while being sponged over with cool or tepid water, than to chill them when their powers of reaction are at their lowest. The soap used should not be irritating from excess of alkali, or from impure and imperfectly-combined ingredients. Babies most easily suffer from this, and also from want of care in the warmth of the water used, or from harsh rubbing; they also suffer many things both from the kind of dress and the fashion of dressing them; a broad band is so rolled on as to compress the abdomen, and comes up so high on the chest as to interfere both directly and indirectly with free breathing; then come complex many-stringed instruments of torture, while thick folds of linen, flannel, or even macintosh, curiously involve the legs; over all comes an inexplicable length of garment that is actually doubled on to the child, so as to ensure every form of over-heating, pressure, and encumberment. After a month of this process, aided by hoods, flannels, shawls, and wraps of all kinds, a strange variation is adopted; the under bands and folds are left, but a short outer garment is provided, with curious holes cut in the stiffened edges, so as to make sure that it shall afford no protection to legs, arms, or neck, if it were, indeed, fashioned to cover or even come at all close to them. To prevent the possibility of this, and thoroughly to expose the chest and arms, a string or ribbon ties the edge of the degenerated or absorbed neck or shoulder-piece to what remains of a rudimentary or metamorphosed sleeve. It is interesting to know that this picturesque fragment of some past phase of dress development can be preserved without the sacrifice of effective covering by inserting a close sleeve, or putting beneath the frills a little knitted jacket; or one of soft texture can be made to go moderately high on to the neck, with a seam over the shoulder to let it lie flat to the upper part of the chest, and a sleeve cut with a good angle for the elbow and a very short inside seam; this bit of clothing, if of nice material and colour, has a pretty effect under the open-work embroidery, thus shown off to advantage without risking the exposure of half the child's body. Effective protection of the other half, which it is most important to keep warm, presents greater difficulties. Much irritation is produced by keeping damp clothes close to the skin, and more when caustic soda has been used in washing and is left from careless rinsing and drying. All impervious wraps are to be avoided; there must be frequent changes of linen. An infant's tender skin has to be kept dry; it is soothed and protected by the use of violet powder after being washed. The best toilet powders are, in some degree, antiseptic, and are constantly improving in this direction. French chalk, white fuller's earth, or Taylor's Cimolia already replace starch, and, instead of orris-root, eucalyptus oil, menthol, or boracic acid might be used in nursery powder; the latter is now in use under the name of Sanitary rose powder.

CHAPTER LXXXIV.

Heat of Rooms—Of Baths—Thermometers—Effects of Heat and Cold.

YOUNG children bear cold badly. In removing them to a separate room means must be taken to secure moderate warmth. Sudden changes of temperature are to be avoided, and special care must be taken against any long continuance in a low temperature. A small child soon loses heat, and is most depressed by such loss during sleep. In many cases of illness or weakness a fall of ten degrees in the child's room may be of the utmost injury. Besides proper means of warming children's rooms, and care to see that windows are closed in cold weather after the air of the room is changed, the chamber thermometer, an indispensable requisite for the nursery, must always be consulted. The bath thermometer, with its metal trough and high index, often extending to the boiling-point at 212°, does not answer the purpose; and, moreover, should always be kept in the bath-room to be ready for use in any bath, whether cold, tepid, or hot; but a cheaper instrument, mounted on wood, with more open register, the degrees from 30 to 100 conspicuously marked, should be so placed in any room that the variations can easily be noted.

A portable thermometer of this kind, with sufficient sensibility to show the variations of temperature within a few minutes of being moved from one room into another or into different parts of the same room, is sold for a shilling. Such a thermometer required ten minutes to show a variation of five degrees, from 52° to 57°, on being moved from one room to another, both with closed windows. Compared with an accurate instrument, this cheap one was very correct from 40° to 90° and fairly sensitive, therefore quite useful as a fixed chamber thermometer, but not fitted for use in the bath. The upper register was slowly reached, and not to be depended on above 100°, just at the critical point for the proper limit of temperature in a hot bath. The two instruments have bulbs of the same size, each with tubes six inches in length, the more accurate one is graduated to 235° Fahr., the other is marked to 120° in the same space. The latter is less adapted to general use, as the wood frame on which it is mounted retains heat for some time, especially after immersion in hot water. Either of them carried from a room at 55° to one at 65° will rise one degree a minute at first, but instead of both continuing to rise at this rate so as to mark the full difference of temperature in ten minutes, the cheap thermometer after four or five minutes moved one degree in two minutes, and then one degree in three minutes, and finally took half an hour to show the true temperature of the room. On moving them from a warm to a cold room a similar rate of fall was observed. This rate will of course be the same in showing differences of temperature in different parts of the same room. A spirit thermometer is even slower to rise, and longer in losing heat. A thermometer kept always in the room is the best guide to its true temperature. Spirit may do very well for a stationary thermometer; a mercurial thermometer is better for moving from place to place. If a child and a thermometer are moved into a cold place together the child may suffer from chill before the thermometer has had time to show how low the temperature really is. In dealing with higher temperatures or with greater differences

in temperature than those here concerned, much greater rapidity of rise or fall is shown by mercurial thermometers. The standard one here used, in water at 180° rises 80° in five seconds, and 40° in the next ten seconds; it takes less than two minutes to reach its highest. Replaced in air at 60° it falls 80° in five minutes, and takes more than another five minutes to complete its fall. In water at 130° it rises 40° in five seconds, and after removal falls a degree each second for the first half-minute, then 20° degrees in four minutes, and finally falls a degree a minute. My clinical thermometer in water at 110° rises nearly to the full height in five seconds, and completely so in ten seconds. On plunging the two ordinary thermometers in water of this heat, both rose to 100° in ten seconds; in half-a-minute 5° more was marked by the more accurate of these thermometers, which was hardly indicated on the other. They remained, one four degrees and the other eight degrees below the true temperature, a serious defect in the matter of a hot bath. Every bath thermometer should be compared with a good clinical thermometer at the register from 95° to 105°, so that errors may be allowed for; or, avoid hot baths for children. A small thermometer with an index of three or four inches, extending from the freezing-point of water to 100° or 110° of Fahr., answers very well for rooms. The Centigrade thermometer is in universal use for scientific purposes. The zero for this is at the freezing-point of water, that of Fahrenheit is 32° below. Many of the ornamental forms made abroad are marked on Réaumur's scale, and if our own have not the Réaumur degrees marked on the right of the index, they all have the words freezing, temperate, summer-heat, and blood-heat put there exactly at 0°, 10°, 20°, and 30° of Réaumur's thermometer. These are the limits on the various thermometers in use of every-day importance. For extreme heat we may add the degrees 113°–122° F., represented by 36°–40° R. and 45°–50° C. For indoor purposes the line marked temperate should be raised to 60° on our thermometers, to 12° R., and 15° C. at least. 75° F., or 19° R., and 24° C., is as high as the indoor temperature should be allowed to reach without adopting artificial means of refrigeration.

A comparison of the different thermometers is given in the following table.

TABLE OF THERMOMETRIC EQUIVALENTS.

Practical Notes.	Fahrenheit.	Centigrade.	Réaumur.	Thermometer Marks.
1. Great care in wraps and warmth	32°	0°	0°	*Freezing.*
2. No room to remain below	41	5	4	Cold enough for larder.
3. Fire or extra clothing required	50	10	8	
4. Lower limit of temperate	55	12·5	10	*Temperate.*
5. Mean temperature	59	15	12	Cold bath.
6. Upper limit for heating rooms	68	20	16	
7. Artificial cooling required	77	25	20	*Summer Heat.*
8. Care in out-door exercise	86	30	24	Tepid bath.
9. Lower limit of depressed body-heat	95	35	28	Warm bath.
10. Normal body-heat	98·6	37	30	*Blood Heat.*
11. Fever heat	104	40	32	Hot bath.
12. Extreme temperatures borne by the body	113	45	36	*Fever Heat.*
	122	50	40	Vapour bath.
	140	60	48	Water scalds.
	212	100	80	*Water boils.*

The italics in the last column are words marked on most thermometers; excepting the first and last terms, which are fixed points, their object is utility rather than accuracy; some comments useful in preparing baths are added to this column. The temperature of the room is a fair guide for the cold and tepid bath. It is well to add a little warm water to the children's bath, or to wash them in warm or tepid water, and sponge over the surface with water of the temperature of the room, just before drying with a warm towel and gentle friction. The ablution of young infants must always be in warm water about 90°, or raised as much above the temperature of the room as the nurse may judge necessary; here the sensation of the hand and arm may generally be trusted, but the correctness of the estimate should now and then be tested by a thermometer. A warm, or hot bath, for the complete immersion of a child, should never be given without careful use of an accurate thermometer. A temperature of 98° is quite enough to begin with, and even then the child should be immersed gradually and gently. For the relief of pain a heat of 99° or 100° may be required; if so, the child should be removed on to a warm flannel while more hot water is added, and the exact thermometric degree obtained. No hurry is ever allowable in preparing a hot bath. Many of the emergencies for which a hot bath is recommended would be more safely managed with merely a warm or tepid bath. Time is also required for consideration as to whether a hot bath is appropriate; it is seldom proper during febrile symptoms of any kind; elevating the temperature of the blood above the normal is a stimulus to be used with caution; warmth just sufficient to dilate the surface circulation, while still below the body-heat, cools the blood as it comes by successive pulsations in contact with the surrounding medium, and often gives much internal relief. Any sudden impress of heat tends to close the surface-vessels, much as the shock of cold would do, for the moment. Too warm a medium, beyond the excitement at first produced, rapidly induces exhaustion in young creatures.

In looking along the thermometric scale it will be seen that only one-third of the narrow limits given is consistent with life, health, and comfort. All active function in ourselves, the higher animals, and birds, is carried on within the few degrees from 95° to 105°. Life, in hybernating and cold-blooded animals, maintains their temperature a little above that of the surrounding medium. Many means provide for the protection of organised beings against extremes of heat and cold; an organism may resist extreme cold that would be destroyed if subjected to either of the upper limits given. Most organised products, and consequently all clothing, is destroyed at 260°. Any organic germ is destroyed at a dry heat of 240° sufficiently prolonged. Water scalds at 140°; it will retain this dangerous degree of heat for more than an hour in a covered tea-pot, a fact worth remembering in connection with the risks incurred by neglect of timely removing tea-things from the reach of children after breakfast and tea. Young children suffer much from the direct effect of a hot sun, or from hot weather and out-door exertion during the hotter parts of the day. Not only is sun-stroke, or the fever of insolation, a danger, but the enervation from heat renders children specially unable to resist many of the diseases of warm seasons, particularly diarrhœa. Besides, care as to the time for, and duration of, exercise and exposure in hot seasons and climates, cooling the room by ventilation, perhaps with evaporation outside and ice within, should be attended to. The degree of warmth that enfeebles us is also that most

favourable to many lower forms of life inimical to ours, and to many of the disintegrating changes on which they flourish; great care is therefore necessary in keeping rooms, inside and outside, clear of all refuse that might favour their development; also that no remains of food are left in dwelling-rooms, nor any article of diet kept there.

In warm weather various methods of artificial refrigeration will be required for the food kept in the house. A porous cover for some things, with means of evaporation, will answer, or ice can be used. It is not always easy nor convenient to keep the larder below 50°, yet there is risk in having any kind of food day by day in rooms at the temperature suitable for one's own health or comfort. There are other reasons to be given farther on for not allowing milk, bread and butter, biscuits, or fruit to be kept in the nursery, but here it is well to insist on one particular point—viz., that the temperature of a room for children to live in should be higher than that where food can be safely kept; and, conversely, that a room cool enough for a larder is not fit for a nursery.

Short contact with quite cold air or water is injurious to infants; prolonged exposure to the low temperature of a cold house or chamber still more so; most so when the air is not only cold, but damp. In houses otherwise healthy, the onset of acute disease in children, of inward congestions, glandular swelling, tubercle, dropsy, has started from the occurrence of unusually low temperature in their rooms, during exceptionally cold weather, when the means of maintaining sufficient warmth have been neglected, or applied with difficulty. Children are also to be guarded against sudden changes of temperature. After some days in a well-warmed room the first promenade should be short. A child of four or five years old cannot bear a long walk in cold weather, but soon tires, and is then still more liable to suffer from cold. Out of doors, children passing from a sheltered to an exposed portion, the turn of a street, the draught in a passage, may get a chill; or, returning indoors, hot and excited from running or play, the wraps are all removed, though the room to which they have returned is only half warmed, perhaps has become too far cooled, from open windows or neglected fire, they catch cold more on coming indoors than on going out. An infant in arms is often chilled in this way; closely muffled at starting out, carried near the nurse's body, under warm coverings, or shut in a carriage with closed windows, it is brought home, hot and perspiring, and laid down asleep (its load of clothes removed) on a cold cot in the chill quiet of the bed-room, while the other children prepare for dinner; no wonder the youngest suffers first. Not only should the woollen clothes and coverings not be removed at once, but the chamber thermometer should be consulted. Prevention of illness is better than cure, and for both objects a thermometer in the children's room is indispensable. The delicate and expensive clinical thermometer, invaluable in marking the changes of disease, and useful in some of the variations in health when in skilled hands, is often misleading in the nursery; there, its only safe purpose in the hands of the nurse is to test the accuracy of the bath thermometer.

CHAPTER LXXXV.

Development of Children—Weight—Growth.

THE best and most trustworthy means of being assured of the continuous well-being of infants and children is an accurate record of their weight. In infants weight alone may be depended upon; for older children, growth as measured by height must also be noted. The two taken together, if increasing, afford evidence of progress, and, if interrupted, give timely warning of some impending difficulties. At first, gain in weight is much more marked than increase in length; these increments seldom advance in close proportion to each other, though a certain relation between the two should always be preserved. An increase in weight often precedes further growth, and rapid growth is often interrupted while weight is being made up. Particular care both as to rest, occupation, and food is required when a growing child ceases to gain in weight.

The rate of growth for young children varies greatly at different periods of infancy, and follows laws of its own. In the first two years after birth a child should gain twenty pounds in weight and ten inches in height. The chief increase in growth and weight is in the first year, thirteen or fourteen pounds of the gain in weight being in the first year and seven or eight pounds in the second. The third year also is one of active growth, the first dentition is completed, and the child often gains five inches in height with five to six pounds in weight. From three to ten years of age a more uniform increase proceeds, at the rate of about five pounds a year in weight and three inches in height. Unsuitable food, defective teeth, bad hygiene, and the various infantile ailments at any time check nutrition, so that the weight of sixty-five pounds and the height of fifty-four inches, or four feet six inches, is not always attained at ten years of age. Up to this time, sex makes very little difference; girls grow as fast as boys, and often increase as much in weight. Some of the highest figures in both respects are among girls. At twelve and thirteen some girls are as tall as boys, and many weigh as much; but growth sooner ceases.

TABLE OF CHILDREN'S HEIGHTS AND WEIGHTS.

Age.	Common Height.	Extreme Measurements.		Average Height.	Average Weight.	Extreme Weights.		Common Weight.
	ft. in.	Highest.	Lowest.	in.	lb.	Highest.	Lowest.	Stones.
At birth.		22 in.	16 in.	20	7	12 lb.	5 lb.	About ½
1 year.	2 4	32 ,,	23 ,,	28	21	25 ,,	20 ,,	,, 1½
2 ,,	2 8	36 ,,	28 ,,	32	28	30 ,,	26 ,,	,, 2
3 ,,	3 0	39 ,,	31 ,,	36	31	34 ,,	28 ,,	,, 2¼
4 ,,	3 3	41 ,,	33 ,,	38	35	40 ,,	30 ,,	,, 2½
5 ,,	3 5	45 ,,	36 ,,	41	40	43 ,,	37 ,,	,, 2¾
6 ,,	3 7	48 ,,	39 ,,	44	44	51 ,,	38 ,,	,, 3
7 ,,	3 9	51 ,,	42 ,,	46	48	56 ,,	40 ,,	,, 3½
8 ,,	3 11	52 ,,	44 ,,	48	52	62 ,,	42 ,,	,, 4
9 ,,	4 0	54 ,,	46 ,,	51	56	68 ,,	46 ,,	,, 4¼
10 ,,	4 3	56 ,,	48 ,,	53	62	72 ,,	50 ,,	,, 4½
11 ,,	4 6	59 ,,	50 ,,	56	70	82 ,,	56 ,,	,, 5
12 ,,	4 9	64 ,,	51 ,,	59	80	93 ,,	60 ,,	,, 5½

This table is drawn up from records of eighty children, fifty-four of whom were weighed or measured repeatedly. Of these, twenty-six—thirteen of each sex—were under my own observation, some closely during the first year of life for the special purpose to be mentioned farther on, and a few were continuously followed throughout the ten or twelve years of childhood. Twenty-eight children from one year old to fifteen, an equal number of boys and girls, are selected from a register kept by the Messrs. Berry, The Coffee Mill, No. 3, St. James Street, who are always quite ready to assist parents in recording the growth of healthy children, and most obliging to the medical adviser who suggests that this trouble has a useful object; five of this series have the weight entered every year from the first to the tenth or thirteenth year; one has the measurement taken at two years old; several have both records from four years old to seven or eight, and others from eight to fourteen. The measurements of twenty-six children from two to nine years old, sixteen boys and ten girls, are added from notes of hospital patients seen only once, some in London and some in Paris. The hospital cases, if at some ages a little below the average, have only once supplied the lowest measurement at two years of age, and once the highest, that at three years. The highest records at four and at eight years were boys in two families, my relatives, and thoroughly English; at the latter age, a girl of Scotch parentage takes the lead for the next two years, and is then again equalled by two boys, one belonging to a good Jewish family. At twelve, healthy girls always show increased growth-rate.

Divergencies to any extent produced by illness, or obviously abnormal in either direction, have not been taken into account. Lilliputians, however healthy, are not included here. A Gargantua of three feet in length, and seventy pounds, or five stones, in weight, at a year old, who gained two stones in weight in the next half-year, reported from Canada, is not yet admissible into our calculations.

From a report to the Local Government Board, London, 1873, on children in towns or factories, the following tabular results are drawn :—

Number Examined.	Both Sexes. Age in Years.	Average Height in Inches.	Average Weight in Pounds.	Chest-measurements.	
				Empty.	Full.
664	8	46·5	53·3	22·4	24
1,699	9	48·5	56	22·5	24·5
1,999	10	50	61	23	25
1,783	11	52	68	24	26
1,695	12	54	71	24·4	26·5

The boys in this table exceed the girls in number; they are half an inch higher and a pound or two heavier till the ages of eleven and twelve years, when there is no constant difference; the chest-measurements are equal in the two sexes, but the amount of expansion movement is greater in boys than in girls at all these ages.

Two illustrations may be given of changes worth noting in illness. A boy, ten years old, after scarlet fever had lost four pounds in weight; this he regained in one month after convalescence, and added another five pounds in the next three months. A weakly boy, eight years old, three feet ten inches high, forty-six inches, weighs forty-two pounds, and gains no weight and only one inch in height during six months' care in London; he then goes into the country for three months—

August, September, and October—gains eight pounds and grows another inch; at nine years old he gets to the proportions of fifty pounds and fifty inches—the average height but not the average weight, until, after another year of care, he became strong and well. Another boy of this age, the same weight but an inch shorter, made no advance, and then, with slight febrile action, began to lose flesh, till his weight in pounds became less than his height in inches; he did not recover. It may be noted in the table that till the seventh year the height in inches exceeds the weight in pounds, and that, from eight to twelve years, the height in feet and the weight in stones corresponds; as growth is nearer completion, a still further increase of weight over height should occur. A child in the fourth year should be three feet high, and weigh more than two stones; in the sixth year, three and a half feet high, and weigh three stones; in the eighth year, four feet high and four stones in weight; at twelve years old, five feet in height and five stones in weight is a fair average. At the term of adolescence, two stones should be added for three or four inches of height; eight stones for five feet six inches; nine stones for five feet eight; ten stones for five feet ten; eleven stones for five feet eleven inches; and twelve stones for six feet of height is good weight.

Growth is very irregular in children and young people generally; perhaps two inches may be gained in two months, and for the next ten months not another inch, even up to the ages of ten or twelve years. While growth is most rapid fatigue is readily induced; during the pause weight is gained, and work or training can go on again.

The proportion between the age, weight, and height of infants has a bearing on successful nursery management of much the same import as that observed all through the period of childhood. The rapid rate of increase in the earlier months of infancy, and the variations which are then observable, make a separate study of this period essential. A vigorous healthy child should double its birth-weight in the first four or five months, and treble it at a year old. This rate of growth is not uniform, nor does it proceed at any steadily-decreasing ratio, but is subject to the variations shown on the diagrams farther on. The loss of weight marked in the first few days is constant; it is not owing to the want of nutriment or to the kind of supply given. The most appropriate ingesta are those which aid the clearance of waste material from the bowels and kidneys. If the infant wets the napkins freely it is receiving all it needs in the way of fluids, and at this time the proportion of solid matter to be passed is increased tenfold. A week later, with six times as much urine voided, only half this active waste is evidenced. The natural period of most rapid growth comes to a pause about the fifth month in healthy children, when the teeth are forming, and a further demand on the nutritive supply is made. Care has to be taken lest this pause be unduly prolonged, and a downward tendency advance to positive illness. We see also the first increase of weight checked as growth increases, so that some processes may be less active while a new direction is given to healthy development. Still, for infants under three years of age, weight is the best criterion of progress.

For children of three years old and upwards, height and weight must always be taken together; in order to judge of healthy growth it may be sufficient to do this three or four times a year. Under the age of three years weight alone gives all the indications required, and children obviously healthy need not be weighed oftener than

every two or three months after the first year; every month is enough for this after the first few months. At first an infant should be weighed every week. A weighing-machine is, then, a necessary for the nursery. An ordinary household balance, turning at half a drachm, with weights from a quarter of an ounce to a stone, should be kept for the systematic observation of the steady increase that ought always to be found after the child is a week old. A set of metric weights might be provided for scientific accuracy. A piece of dry flannel on the balance to receive the child, and the swathing band in ordinary use, should be first weighed, and their weight deducted from that obtained from placing the child, washed and dried, with nothing but the swathe around, in the warmed flannel on the balance. This might be done almost every day when the child is being washed and dressed; it should always be done at the same time, and, as nearly as possible, under the same conditions, slight differences as to ingesta being allowed for or corrected. Fig. 407 is a diagram of the rate of increase for the first year:—

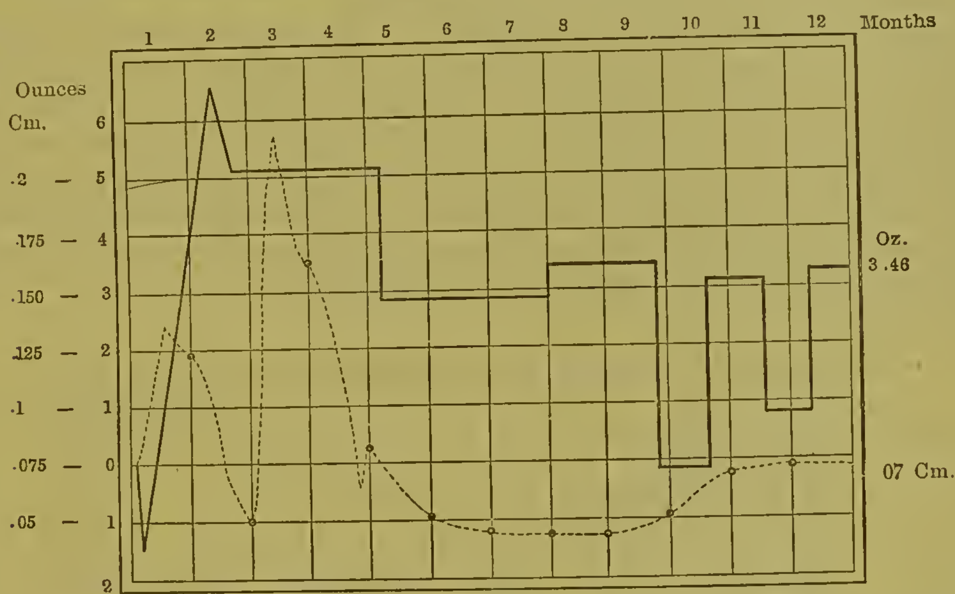

Fig. 407.—The black line shows the Average Weekly Rate of Increase in ounces. The dotted line gives the Average Daily Growth in centimetres—two-fifths of an inch—from measurements by Dr. Haehner.

At first, under the new conditions of life, there is always a *loss* of weight, amounting on the second and third day to three or four ounces a day; so that a child three days old may weigh half a pound less that it did at birth. This is called the physiological loss, and is said to average 6 per cent. of the birth-weight. Nutritive matters, or the waste of past nutritive processes, stored up in the body of the child, are now utilised, and the way is cleared for new material to be readily assimilated. Very soon after food is taken freely the loss of weight ceases; often a gain begins on the fourth day. The first loss in weight is mostly, or should be always, more than made up before the end of the first week. A progressive increase of weight now goes on at the rate of two or three ounces for the second week, at four and five ounces for the next two weeks, and at six ounces a week, or even an ounce a day, in part of the second month, when the increase is greatest. For the next two months a uniform gain at the rate of five ounces a week is maintained, while growth is more rapid than in the previous month. In the fifth, sixth, and

seventh month the rate of increase for weight falls to three ounces a week; growth also pauses a little, and both undergo some variation while dentition is proceeding. The diagram of these changes will serve to fix attention on normal progress of infantile growth, and as a reference-table by which any slight departure from health in the earlier months may be at once recognised, and so lead to the detection, perhaps to the removal, of its cause before any serious interference with sound development has occurred.

By these tables the rapid rate of growth after the first week is seen at a glance. The critical time for making sure that the infant is obtaining the proper supply of food, and is thriving on it, is in the first six weeks, and there is no means of doing this so reliable as weighing. In this way the check to nutrition is often discovered before any of the painful, and often unmanageable, symptoms of athrepsia are declared. There are some conditions unfavourable to the health of infants not discoverable by weighing, but this means would serve to point out the most frequent of them in time to avert their worst consequences.

Much of the comfort and happiness of all concerned depends upon the uninterrupted well-being and steady nutrition of infants in the earlier months. Regular and systematic weighing, as the only trustworthy criterion of healthy infantile progress, has of late years been widely adopted in the public institutions of France and Germany. We are indebted to Anna Angell, of the New York Infant Asylum, for many hundred careful observations, week after week, for a year. The results agree very closely with those obtained by other observers; they are approximately given in the following diagram, Fig. 408.

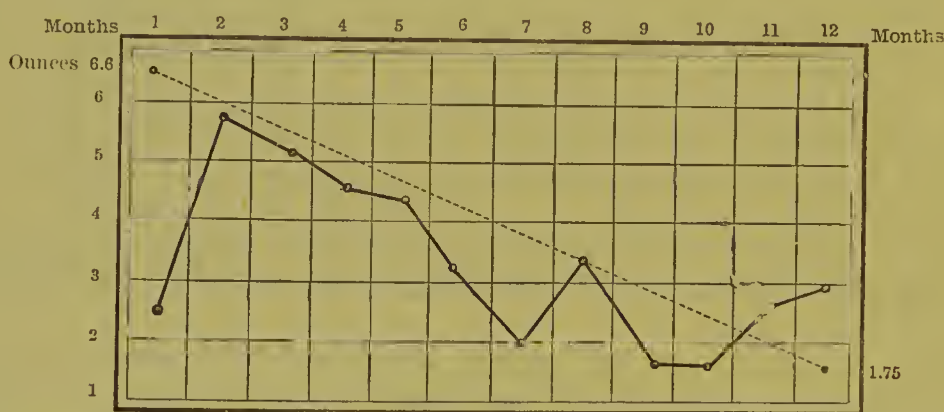

Fig. 408.—Average Weekly Gain in Weight for each Month, drawn from observations by Dr. Anna Angell, of New York. The dotted line shows Bouchut's estimate of the Progressive Decline in Rate of Growth.

With big children the rate of increase is rather greater than in the small and weakly. A rather higher average is found for boys than girls; the boys may have at birth an excess of ten ounces in weight and half an inch in length, but this is of very little importance, as individuals of either sex may commence life at a weight of nearly two pounds, more or less, than the average. Setting aside the extremes, and taking children who are within a pound weight either way of the ordinary size at birth, there is less difference than might be expected in the rate of growth after the first year. This is also true for the difference in sex, and exactly corresponding weight and measure for both sexes at each age up to ten or twelve years occur.

CHAPTER LXXXVI.

Change of Air—Ventilation—Amount of Free Air-space required in Rooms in Health and in Illness—Position of Rooms for Children—Arrangement of Room.

The robust aspect of healthy children is good evidence of the thorough hygienic state of the dwelling-house, and of the excellence of its domestic management. A ruddy glow in the face of a child tells at once of sufficient outdoor exercise and indoor ventilation. Without a full amount of fresh and pure air the cheek loses its colour and the flesh its firmness; the blood is impoverished, its circulation languid, and nutrition is interrupted. The effect of what is called "change of air" in stimulating these processes is well known, and particularly obvious in children. Very often the good that would be done in this way is put in jeopardy by too much attention being directed to the particular place where this change is to be obtained, and too little to the sanitary state of the house and the size of the rooms to be occupied. Perhaps the smaller bed-rooms are allotted to the children, unmindful of the fact that they spend nearly half of the twenty-four hours continuously in the bed-room; or they have but one room for meals and for play, so that if kept indoors by a wet day they have to pass many hours together in one room. It may be that neglect of some of these particulars at home has occasioned the necessity for the change; if they always received the attention deserved, both at home and abroad, periodic visits to so-called "health resorts" would be required less frequently; and, we might find a more uniformly healthy appearance among the children of the residents at these places.

The importance of careful and efficient ventilation of the rooms occupied by children can hardly be over-estimated. The air of a closed room soon loses its freshness even when unoccupied. Chemically the proportion of oxygen may not be appreciably altered, but the more active, or ozonised, part of it is changed; innumerable particles are brought into contact with it which, if not "stealing and giving odours," may add what is imperceptibly injurious, and will certainly take away from it the quality of freshness. Movement of air through a room is a first essential of ventilation; then the quantity and rate of movement has to be considered, taking care that the temperature, and other qualities, are so preserved as to be both pleasant and wholesome. These questions have, however, been already considered in the chapters on Ventilation.

Exact comparisons are wanting as to the relative amount of respiratory products between children and adults; children, though with smaller organs, have more activity of function, a quicker rate of breathing, and tissue-change is rapid. Instead of considering two children as one adult in the cubic space allotted and the amount of air per hour required, "the safest course is," Dr. Parkes observes, "to have the same rule of whatever age, excepting the very youngest and oldest, who require special conditions of warming." He also adds, "If any difference is made, children ought to be considered as evolving not less than 0·45 of a cubic foot of CO_2 per hour: the amount 0·6 ought to be retained for women, and 0·7 ought to be allowed for men. In this way the minimum hourly

supply in health in repose ought to be for children 2,250; for women 3,000; in ordinary sickness 3,400 and 4,000 cubic feet respectively." A larger initial cubic space is required for a room that has to be continuously occupied for some days and nights, than for one occupied only at night; again, the space required in an ordinary bed-room for each person is greater than is always necessary in a room only used for a limited time, as for meals; in these rooms a greater amount of air can be admitted at one time, and they can be swept through with fresh air at more frequent periods.

The efficient ventilation of a child's first nursery, under the special conditions of warmth required, demands a full allowance of cubic space to begin with. In calculating the necessary space for bed-rooms, where equable warmth is required, any height exceeding ten feet is disadvantageous and to be left out of account. A good bed-room should be twenty-five feet square, giving a clear 2,000 feet for each occupant after deducting the space taken up by furniture.

The nurse's room should be not less than 15 feet square, if the child has to sleep there; no food is to be kept or prepared in the room and no clothes dried or aired there; moreover, a convenient lobby must provide for the immediate reception of all that has to be removed; soiled clothes should be taken out at once, and covered with a weak deodorising solution. A child until two years old, must sleep with the nurse, and requires as much space as an adult.

If any accident or illness befall a child, not only separate care but an increased air-space is at once needed. It has been calculated that a single drop of decomposing matter from a burn or abrasion of the skin would supply one hundred million diffusible particles, or "germs," to the air; or from five to ten times the number likely to be found in the atmosphere of a good-sized room. With the most scrupulous attention to every detail of cleanliness, to keep the air pure, it is still necessary that invalids should be changed from one room to another during illness, and afterwards removed for a change of air altogether. What has been called the two-room treatment of disease should always be adopted; for infectious diseases these rooms should be in the upper part of the house, or on a level above the nursery floor.

Ventilation of the spaces under the floors of houses is very necessary; gratings in the opposite walls should admit air-currents between the floors and ceilings; any evils from chilling the floors are less and more easily obviated than those arising from the heated and stagnant air of the spaces beneath. Organic particles from the room penetrate and settle in the joints of the boarding, or are scoured into them, with moisture enough to make them dangerous. The temperature of these spaces beneath the boards often becomes higher than that of the room—much higher near any stove or fireplace, and remains long at the point most favourable for the development and activity of infectious particles.

The sleeping-rooms for children should never be at the top of the house, or there will be tiresome stair-climbing; the day-room should never be in the basement, as arranged for in some otherwise good suburban houses, for the air of a room below the ground-level can never be dry and pure. No sink or cistern is to be placed on the same floor as the nurseries. The position of the closet has received full notice elsewhere. Any water-closet, of course, will project beyond the walls of the rooms so as to allow of cross ventilation and preclude

all air entering from it to the house. The cistern for the supply of this closet will be out of doors, covered, and sheltered from the sun. Warmth fills any space above the water with vapour that readily entangles organic particles, and favours their increase. An indoor cistern is likely to give off malarial moisture as well as itself to receive taint.

Drinking-water should be brought up fresh, filtered, and kept cool. Children require a large supply; this may be supplemented by some drinks, as lemon, or toast-water, made with boiling water, which has been thus further purified; it will remain fit to drink for a day or night, if covered, in a cool place, and not kept too long. Any tap for drinking-water is never prudent; nor should there be a tap for any domestic supply of water near the nursery. A tap implies a something to catch drops from it, and so either a damp surface is maintained, or there must be a pipe to carry off the overflow, which, if it conducts nothing bad into the house from a distance, becomes the source of multitudinous particles that will ferment everywhere. So with a sink, however ingenious the trapping, foul air returns by the waste-pipe. Let this be as short as possible, just so as merely to pierce the wall, and open with a free end over a catch-basin; the pipe will be foul even if only clean water pass through it, and it is difficult to prevent it becoming part of the ventilation of the house, mostly as an inlet. The manifest convenience of having a sink near to rid the nursery department of soiled water has to be weighed against the tendency of all servants to misuse such convenience, and it is best to decide against such sources of mischief, and to make the best of a well-placed lobby or closet for the temporary reception of waste. All slops must be carried down to some place in the basement; washing up is best done below stairs in some outhouse or scullery. The waste-pipe of the bath is a difficulty; it must be short, and end directly in the open air without any close connection with other pipes or drains; the bath opening of it should be kept closed when the bath is empty. The bath-room is often a vestibule to the closet, or an offshoot of the dressing-room; where a lavatory may be convenient, the washing-basin should open into a removable slop-jar beneath; and, if this is in a lobby to the closet, besides a small hand vessel there, a wooden frame ten inches square, with a movable round lid, should cover an ordinary chamber-vessel, a little raised, and so placed as to be ready of access for children.

The day and night nurseries are better situated on separate floors, or at some distance apart; where this cannot be done, they should be arranged not to communicate directly with each other, so that one set of rooms may have the windows left open to the air for a good blow through, without fear at the same time of the other room being chilled. There are points in the general management of the two kinds of apartments that may be considered together so as to contrast their special requirements. The day-room is for cheerful activity, the bed-room for quiet repose; hence a great difference is in the way of lighting the rooms. All rooms, whatever their purpose, should be well lighted, so that everything in them can be distinctly seen, and no part left in obscurity and in danger of neglect; and the door should not be directly opposite the fireplace in day-rooms, without a special contrivance for ventilation, to be described farther on, as the draught is mostly from under the door to the fireplace, and so along the floor; this can do no harm in the bed-room, but is bad in a sitting-room, and specially bad for children, who do, or should, spend much of their daytime in creeping or playing on the carpet. The windows are a great

means of ventilation as well as of lighting, and can be used either as outlets or inlets of air; they should not be near either the door or the fireplace, for in ventilation the outlets and inlets should not be near together; the door is always an inlet, and the fireplace should always be an outlet. The windows and doors are better opposite each other in most rooms; in a sitting-room or work-room there should be windows also opposite the fireplace, and on two sides of the room, so that light may fall both behind and to the left of the reader or worker. No bed should be placed just between the window and the fireplace in a bed-room, and the windows in the day-rooms should be large and low; in the bed-rooms the old-fashioned broad window, either side made to open, or the dormer window, might reappear. In the bed-room less light is needed, more care is required as to draught, nor do children want to be constantly looking out of window. Moreover, a large window is the great cooling-surface in a room, one which cannot be banked up and shut off by thick heavy curtains, as in the sitting-room, nor can its cooling effect be counteracted by a jolly fire; that would be disturbing and out of place in the children's sleeping-room. Neither thick bright carpets on the floor, nor pretty patterns on the wall, nor shelves, nor books, nor pictures, nor the endless little ornaments and toys of the sitting-room and play-room, would be in place in the bed-room.

Just as no article of food and no part of the service for meals is to be kept in the day-room, so neither are they, or any clothes or linen not in use or on the beds, to be kept in the bed-room. All cupboards, closets, and wardrobes diminish by their size so much of the cubic space calculated for fresh air, and most contain things that tend to spoil its freshness. A closet built up to the ceiling in the recess by the side of the fireplace is better than a wardrobe; no dust can settle upon it, and it can be more easily cleaned and rubbed inside. The store-room will be in another part of the house, and all airing and drying of clothes should be done away from the nursery.

There should be a dressing-room in close proximity to the bed-room, where the children's clothes can be left in readiness for the morning. A fire can be lighted here on cold nights and mornings, or hot water brought; a fan-light over the door of this room would convey light enough to the nursery for the night. The nurse's room must communicate directly with the children's bed-room, and so give them sufficient light. The nurse must have means of illumination at command; a candle, with a glass shade ready, can be lighted at the night-light. A covered vessel over an ordinary Child's or Price's night-light will serve to keep food warm for an infant. A gas-light in a lobby, with glass over the doors leading into both rooms, is easily turned higher when wanted, either for better light, or for warming food with a proper arrangement. There is always risk in using spirit-lamps in the nursery; the open flame is most dangerous, and the safest lamp may be upset. A solid-flame spirit-lamp, with stand, kettle, and other additions, affords a convenient method for warming food, or even for boiling water, in the night. This is better done out of the bed-room, not only to avoid a chance of accident and the disturbances of noise and glare, but to prevent the possibility of food being brought into the room before it is wanted. Milk is specially prone to absorb into itself any volatile or organic emanations floating in the air; and the very qualities that adapt it, in a way that no other food is adapted, to be the most suitable nourishment of a child, render it more

liable to convey injurious particles to the child's actively-absorbent surfaces. Any article of food brought upstairs for the night should be carefully covered, wherever it is placed. Milk requires more care than any other, both as to position and temperature. The nurse should have it brought up fresh at the time it is wanted for use, and see where it is kept; if not left in a sealed can, at least it should be covered, and not put near cheese, game, or remnants of food. For night use, slightly heating it and adding a little salt helps to preserve it from change. The feeding-bottle should be "scalded" after use, and the tube immersed in cold water until it is wanted again. Microscopic germs, and even masses of fungoid vegetation, were found in twenty-eight out of thirty of the caoutchouc tubes and nipples in use at a *crèche* in Paris; in some of those said to be clean some acid milk remained containing *bacteria;* these would soon set up offensive changes in any new milk added, and are themselves known as "germs of disease." A glass cover is very useful to go over biscuits, barley-water, beef-tea, or milk. These things can be placed on a tray ready for use in the nurse's room, if that is not a sleeping-room, or just without if that room is so used. A necessary fixture is a small cupboard with shelf and drawer in the nurse's room for inclosing any medicines and the simpler remedies and appliances likely to be wanted. No bottles are to be left standing on a wash-stand, dressing-table, or shelf; nor is the cotton wool to be put away with linen, but to have a drawer to itself under the medicine cupboard, and as part of it, so as always to be at hand, and not under lock and key. All medicines are to be locked up, and some things, such as liniments, to be under double locks. To admit of this, the medicine chest or shelf, thirty inches long, is fixed to the wall on brackets, and closed in with double doors ten inches high, opening in the middle; one half holds the larger bottles of saline, fluid magnesia, and dill-water, or cod-liver oil, in a single compartment; the other half has a drawer in the lower part, which is to be kept locked, and divisions above for medicine glasses and such medicines as ipecacuanha or rhubarb. A medicine cupboard of this kind is easily fixed, out of children's reach. The key of the inner compartment is not to be left with children or a young nurse.

A room fifteen feet square and nine feet high affords ample initial cubic space for a nurse and two children; with good and careful management, a nurse, infant, and two other young children have occupied a bed-room of this size without detriment to health. No useless articles of furniture or of drapery were allowed entrance; both a dressing-room and a bath-room were close at hand, care was taken to keep the air of the room pure, no open vessels were allowed to remain, the door, never quite closed, admitted light and air from the passage, the two windows were partly open on the summer nights, and the fire always lighted before bed-time in the winter. Children from seven to nine or ten years of age may have separate bed-rooms, and after that age a separate dormitory for each is requisite. A space of fourteen or fifteen feet by eight or nine feet wide permits of a bed four feet wide to be placed between the door and the wall, and a fireplace in the opposite wall to be beyond the foot of the bed. No double-bedded room should be less than fifteen feet square, and no bed-room should be without a fireplace.

A child until two years old must sleep with the nurse, and requires the same allowance of cubic space. From two to five or seven years of age two children may be estimated as one adult in calculating the amount of initial air-space wanted in

the bed-rooms, and this only in rooms of the best construction and management; each candle is to be counted as a child, and every gas-burner as a grown-up person. In well-arranged houses, a good supply of pure warmed air will enter the bed-rooms from the staircase and corridors by spaces purposely left near the floor or under the door; half an inch left under each door, or three-quarters of an inch at the top obtained by bevelling the upper edge of the door, would provide such spaces, which should together be equal to twenty-four square inches for each person; theoretically, the inlets and outlets should be equal; practically, they equalise themselves whatever we do, and one or two grated openings may be placed in the angle of the walls and ceiling. A fire will draw to itself a supply of air, and so ensure ventilation, and perhaps a draught; an open fireplace with no fire in the winter will let in cold air, unless some means of prevention are used. A Galton's stove is so constructed as to warm the air before it is admitted to the room. A fire in the winter should burn up long before the children's bed-time. The room door may be left partly open, and there will mostly be an open door either from the dressing-room or the nurse's room; the doors must be so hung that when partly opened they will shield the bed, rather than direct the current of air on to it. The windows in the summer can be left a little open at the top; they should be provided with shutters, both to keep off draught and to shut out some of the light when this may be necessary; they aid materially in lessening the chill that in cold weather always strikes in from the windows, and then require the aid of curtains for further preservation of warmth. A stout linen or jute fabric makes a good protective window-curtain for the winter. All woollen hangings are objectionable in a bed-room, as they readily absorb moisture and all organic particles suspended in it or floating in the air; the bed-curtains should be confined to the upper end of the bed, and be of dimity or some thin linen material. The ceiling of the room should be such as to bear rubbing over; it is better of a grey or cream-colour than white, so as not to reflect too much light on the upward gaze of children. The walls of the bed-room are better distempered, or painted in some even tone of quiet colour; if the wall is papered, it should be varnished over, and the paper must have no bright-coloured intricate pattern-spots, and no vivid greens likely to contain arsenic. The floor must not be carpeted all over, certainly not under the bed, and it is better to have the boards stained and left bare round the sides of the room; the top edge of the skirting-board should be rounded off in all rooms for children. Iron bed-frames should have round edges. Slips of soft carpet by the sides of the bed, and from the door to the fireplace, if not all over the centre of the room, are sufficient. Kidderminster carpets are better than those of more open texture for bed-rooms, and Dutch carpets, with a smooth woollen surface over a hempen framework, are specially suitable for children's rooms and the passages leading to them.

The materials in general use for bedding are such as comply fairly with the qualities that are required in them and the purposes to be served. Wool, though the best material for preserving the warmth of the body, absorbs moisture very rapidly; but the moisture from the breath and skin contains much that is better not absorbed, consequently, the woollen blankets are properly covered with linen or cotton sheets. Cotton is better for the night covering, as it is very non-absorbent of water, and conducts heat rather less rapidly than linen. Linen makes a very

good covering for the mattress; this should be stuffed with horsehair, and the under palliasse with straw; these are the two materials least absorbent of water and permeable organic matter. Wool and feathers are most absorbent, hence the stout tick and white linen cover requisite for a pillow-case. All hydroscopic substances absorb animal effluvia most freely, and more so if of a dark colour.

Lest the requirements of the nursery, with all these separate bed, bath, and dressing rooms, with store-room, linen-closet, pantry, larder, and scullery should seem more than any moderately-sized house could contain, it may be observed that in small houses these rooms or places that subserve these different purposes necessarily exist, and that attention is properly directed towards keeping them to their various purposes. In the same way every house could hardly furnish separate dressing, breakfast, and dining rooms, as well as morning-room, play-room, study, and parlour, yet there are few houses that could not afford a change of room for breakfast or study, to dinner or play, and it is worth remembering that such change of room after a meal or after close attention to lessons is in every way beneficial and even necessary.

In large houses, the great advantage of the drawing-room as a place to be visited by children for short intervals, when not wanted for the reception of visitors, and while their own rooms are thrown open, is not often taken and made the most of. In a large country house, where space is unlimited, an entire wing of the building can be devoted to the nursery. This can be constructed at right angles to the side of the house occupied by the family; downstairs the children's dining-room can be near the general breakfast-room; upstairs the nurse's or infant's room can be next the principal bed-room, or divided from it only by a passage, while opening also into the central corridor of the nursery wing. This corridor, running the whole length of the block, with rooms on either side, has a passage at right angles from it leading to a closet with lobby projecting beyond the outer wall; in this passage is the bath-room, and on the other side are bed-rooms; at the farther end of the central corridor is the second staircase, with airy landing and thorough ventilation, with which that of the main corridor can either be made to form part or be made independent; at this end will be the store-room for linen, the work-room, and the room for the under-nurse, with perhaps a separate room for a child who is restless or unwell close by. At the other side will be the day-room, either at the end of the building or projecting from it, so as to have windows on two sides of it, and perhaps a conservatory or balcony attached, with steps leading to the garden. Where superficial space is at all limited, the spare room for a sick child and bed-room for the nurse can easily be on a higher floor, and one or two of the sitting-rooms on a lower floor. Here, on one side of the entrance, could be the study, with windows not too large in the longer wall of the room, and on one side only, so that the light may fall on the left front of the children when seated at the table or tables, one placed at right angles to each window; on the other side could be a well-lighted play-room, or room for meals. A spacious shelter might be formed under one of the projecting upper rooms for exercise in wet weather. A separate staircase for the children from floor to floor is a great convenience and comfort, for it would then be readily adapted to prevent the toilsome climb children have to encounter in going upstairs. Each step of the children's stairs should be only four inches high, instead of six inches as in most stairs, or seven to eight inches in some, and the full

width of twelve inches for the flat surface should be preserved, so that space for a second step is available as each elevation is surmounted; a separate handrail at a lower level, about two feet from the top of the step, on either side of the stairs, is a great help to children. The grand staircase of a big house is easier and safer for children than the back stairs, or those usually leading to the bed-rooms; a spring gate must protect the top of all stairs used by children, or be affixed to the landing or passage leading from them to their rooms.

A sunny aspect and cheerful outlook should always be secured for the children's day-room, while the interior should be made as bright and cheerful as possible. In the play-room coloured pictures or illuminated cards could be arranged round the lower part of the room above a low dado, where they would come within easy range of the child's vision, and be protected by varnish. The windows should always be low enough for children to get a good view out-of-doors, or if over two feet above the floor a fixed play-box reaching half way up would enable them to look out easily. Outside the windows there should be a projecting ledge to hold flowers, with a rail round it to prevent anything falling off; a cross rail just outside the opening of the window guards against the danger of children getting out by it, or leaning over the sill. French windows opening vertically are well calculated for admitting plenty of fresh air; these should always have a well-protected balcony outside. A projecting window often adds much to the convenience and cheerfulness of a day-room.

The windows, except for bed-rooms, should always be continued up nearly to the ceiling, and are better lofty than large. In the evening, when lights are burning, they may be opened a little near the top, with such arrangements of curtains as to protect those in the room from draughts. A very good arrangement of sash windows is to have the timber of the lower sill of more than the usual depth, so as to rise two or three inches above the lower edge of the sash; then, if the sash-frame has a depth of four inches, as it commonly has to support plate glass, the lower sash can be raised two inches without any draught of air entering beneath, while a good stream of air enters between the sashes, and is directed towards the ceiling. A Tobin's tube placed by the side of the window-curtains admits air much in the same way.

The fireplace, or hearth, is an essential comfort; it should be protected but not obscured, and the fender is better placed at such a distance as to be a safeguard against accidents by fire than to be raised to any height over two feet, or furnished with grills and gratings; a fender of fine wire with smooth polished top of steel or brass, safely secured at both ends to the sides of the chimney-piece, answers very well while children are playing about the room; the wire keeps off the direct heat from the fire if they are creeping on the ground near, and does not obstruct the view of it if they are standing, or seated at the table. If children never had to witness the nefarious tricks of servants in placing all varieties of cups, platters, shoes, and clothes near the fire the tendency to imitate would not arise, and all risk of accidents be infinitely diminished. Care should be taken that children do not play on the floor in a direct line between the door and fireplace, the door ought not to be opposite but to one side of the fireplace, and they ought not to be allowed to keep near the door.

Even in amusement with toys a good light is of first necessity; let all occupations

be carried on in full light of the windows; before daylight fails it is time for the energy of business to give place to the pleasures of romance, and story-telling may begin, if it is not the time for oral instruction or elementary discipline. Not only must children have a good light while they are busy, but they should not be too intently occupied with small objects at short distances; some toys to be held near the face for blowing through, or too close attention to threading beads, may induce or confirm a tendency to squinting, to weak or short sight, in the earlier years of childhood. A stooping position and too prolonged attention conspire, with other causes, as a child's instruction advances, to produce short-sightedness, this widely-spread but avoidable evil of civilisation. Children are sometimes seated on insufficiently-raised seats, and so have their faces too near the table. The ordinary tables both for meals and for books or pictures should be somewhat less in height than the average dining-table. Besides the high chair for infants, with its lower part convertible into a table on occasion, several low chairs, and a low stand or table big enough to set out an ark or a toy farmyard, should be provided. The top of this, fifteen inches from the floor, can be raised or extended by a movable board kept for the purpose. The little chairs should be eight inches high, with seats nine or ten inches square; others measuring twelve or fourteen inches in each direction are useful for children of all ages. The infant's chair for sitting at table is usually twenty-four inches high at the seat, with a foot-rest five inches below that. Another is made twenty-two inches high, with a foot-rest at six inches; the seat can be raised by a cushion. A child seven or eight years old requires a chair twenty inches high, with a midway foot-rest.

The tables for meals or lessons should not be more than 2 ft. 3 in. high; a foot-ledge can be fixed across one end of the nursery table for the younger children; a cross-bar joining the table-legs at a lower level may be used by others. Dining-tables are nearly 2 ft. 6 in. high. Some dining-chairs are 1ft. 6 in., not high enough for young people under twelve years of age; a cane-seated frame, with raised back-piece, can be added to the chairs, and a footstool, or hassock, placed for the feet. The keyboard of a piano is 2 ft. 3 in. high; for children, a high chair, with low back and movable foot-rest, should take the place of the music-stool.

The increase of short-sightedness with the increase of education is an evil so important to guard against and prevent, that some of the rules to be observed during the hours of instruction will be explained. Short sight is more frequent among children who begin book-lessons very young. Children of three years old should be taught their letters on picture-blocks. No lessons should be of more than half an hour's duration for those under six years of age. The type should be large in books for the very young. Insufficient or ill-arranged light obliges us to lessen the distance between the eye and the book; this is done in twilight, and must occur if the desk and seats are not rightly proportioned. Ten inches should be the least distance between the eye and the book, and copy-books should not be placed straight upon the desk, but so that the lines slope upwards to the right; a straight down-stroke can then be made without bringing the left eye too near the paper, or giving a twist to the head and body. For writing, the paper should be raised by an angle of 20°; for reading, the book is better raised to 40°; the two eyes can thus be moved along the lines without fatiguing the muscles or compressing the eye; then the book must not be too far on the table, or the child

will have to sit on the edge of the seat and lean forward and press against the chest, or use the arms in support. The seats must have backs, not too high, and not standing backwards; the back ought to be straight, with a firm bar of wood about three inches broad to come across the loins close above the hips. The seat should be broad enough to take the whole length of the thigh, and a foot-board should be so fixed as to let the foot rest naturally on it. The edge of the desk must be perpendicularly above that of the seat, and just high enough to allow the elbow to rest on it, without displacing the shoulders. For school-work the back of the seats should consist only of the support before mentioned; for boys it should be one inch lower than the edge of the table, and for girls one inch higher than the table. Too long a time at once is often directed to lessons; the length of application or attention has to be varied with the age of the child.

Not only short sight, but various spinal deformities, result from inattention to the above directions. The reciprocal influence of seats and lighting is well insisted on by Mr. Liebreich; he says, "A back-rest is necessary to avoid short-sightedness, and good light is necessary to avoid curvature of the spine. For preservation of sight, as well as of a normal figure, the possibility of remaining in a normal posture during school-time, and especially when writing, is an absolute necessity."

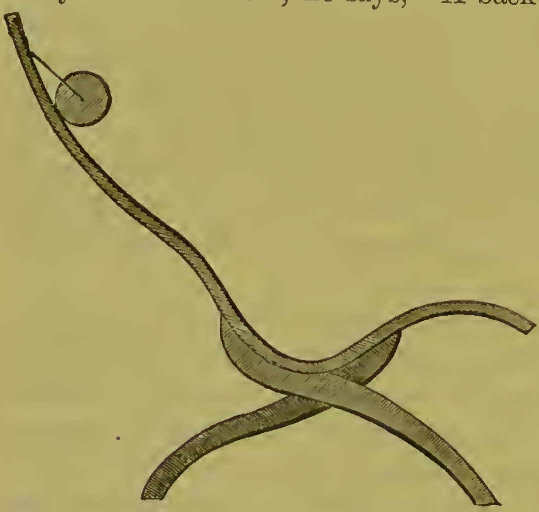

Fig. 409.—Chair giving Perfect Rest.

The subjoined figure (409), from Mr. Liebreich's lectures on "School Life on its Influence on Sight and Figure," is, with his permission, appended as a model of a good chair for the complete and easy rest of the body. The essential part of this chair is the firm upper surface bent to follow the curves of the spine, and so give complete support and rest to the back. By prolonging the lower end a little downwards, and adding a projecting foot to the lowest part of the back, the framework is done away with, and the bent board will stand firmly anywhere, and form a very convenient reclining-board. Messrs. Callaghan, New Bond Street, are the agents for this simple structure. Such boards are very useful, for a rest of ten minutes, in relieving the fatigue of the upright position, or in the intervals of lessons when active play is not to be had. By means of easy rest and varied exercise, rather than by the rigid back-board and wooden foot-frame of a past age, we may hope to avoid the tendency to spinal curvature and short-sightedness so frequently met with.

A careful hygiene should guard the early training of childhood from every hindrance to full development, and from all interference with growth, activity, and health.

HOUSE-CLEANING.

By Phillis Browne.

CHAPTER LXXXVII.

Ordinary Daily Cleaning—Beds and Bedding—Dusting—Spring Cleaning—The Kitchen and Offices—Washing—The Larder and Outhouses.

We all know what it is to enter a house which has been shut up for any length of time. How close it is; how "stuffy" it feels. The dust lies thick on the floors and ledges; the windows look dim and murky. The builders may have built the house of the best materials; it may have been constructed on the most scientific principles, be perfectly drained, thoroughly ventilated, and supplied with every appliance for health and comfort, yet it will not be fit for human habitation until it has been well cleaned.

Suppose we send our servants into it with soap, water, sand, scrubbing-brush, and broom, and have it cleaned from attic to cellar until it is fresh and bright all through; how long will it remain so? Not a day. The maids may commence at the attic and clean downwards in the orthodox manner, removing the dirt as they go, and carrying it vigorously before them; by the time they reach the cellar door the attics will be ready for them again. The moment which finds a room perfectly clean is the moment in which it begins to get dirty again. If once we commence a war against dirt, we can never lay down our arms and say "now the enemy is conquered." The very fact of our doing so would prove that he was gaining ground on us. The fight must be waged without intermission, and the moment of rest is the moment of defeat. No one need fear the conflict, however. The habit of perfect cleanliness, once acquired, soon becomes second nature; and a person accustomed to the absence of dirt would find its presence unbearable. To such a one there would be no pain in fighting the battle, the misery would be in maintaining a truce.

Women—mistresses of households, domestic servants—are the soldiers who are deputed by society to engage in this war against dirt. Let them not make the mistake of regarding the foe against whom they stand as insignificant and not worth an attack. Where dirt reigns, disease, misery, and crime stand erect around his throne; liberty, progress, and enlightenment hide their heads in shame. All the great plagues which have destroyed human happiness, broken women's hearts, and made children orphans, have held their carnival in the midst of dirt. Where dirt has been driven out, purity and enlightenment have found a congenial home; and it has always been found that to become clean is to take the first step in becoming good, wise, and great. Moreover, the individual who has realised the satisfaction belonging to cleanliness becomes sensitive to the discomfort and unwholesomeness of dirt. Various sanitary improvements which have been introduced of late years have arisen from a deep-rooted dislike to dirt.

There is a right way and a wrong way of setting about even such a simple thing as keeping a house clean. In every trade there are certain methods of procedure, which experts know of and adopt, and are thus enabled to do their work well and easily. This rule prevails in household work as well as in other occupations. It is no more natural to a woman to be a cleaner than it is to a man to be a joiner. One reason why so many domestic servants fail in their work is, not that they are unwilling, but that they have not been trained to the right methods. A skilled housemaid, for instance, will, without bustle or hurry, and with comparatively little fatigue to herself, keep a house clean and preserve the furniture, while an untrained one will toil and bustle, and put forth all her energies, and yet not achieve nearly so much, and very likely also injure half the articles she cleans, simply because she does not know how to set about her work.

All mistresses have found what a comfort it is to have a servant who understands her duties, and also what mischief may be done by a girl willing and physically strong, who does not understand them. It is quite true that skill in manual labour cannot be gained by reading about the work. The best methods of doing it may, however, be pointed out in writing, and if the knowledge thus gained be carried duly into practice skill will follow as a matter of course.

In domestic management, quietness and ease are signs of strength and skill. When household work is done with difficulty, and the effort involved is unpleasantly obvious, it is generally badly done. If we hear the wheels of machinery creaking and groaning, we say at once that oil is wanted, and we expect that the work will be spoiled. If they run smoothly, we think the machine is a good one; the machinist understands his business, and we are not astonished to find that the work is well done.

Method and system are to household work what oil is to machinery—they make things go smoothly and easily. In every household, be it small or large, let a carefully-conceived and well-arranged plan for regular cleaning be laid down and duly observed. System consists in having a clear understanding of what has to be done, when and how it is to be done, and arranging who is to do it. If the arrangement be a practical one, if the work is not beyond the powers of the workers, and if sufficient time is given for its due performance, the house will be kept clean, and that is far better than "cleaning it up" after it has been allowed to run down.

A very important point in the arrangement is the division of work. This should never be left to chance, for attention to it is one of the secrets of good management. As in a campaign each officer is told off to a particular duty, let each servant in a house, and each member of the family who can take a part, understand clearly what is the duty for which she is responsible. In large households this division of labour is arranged for as a matter of course. It would be an advantage if the plan were universally adopted, and if every one in the house would do his or her part, not in cleaning, but in preventing dirt by the practice of cleanly habits. Even children might be trained to do this from their earliest years. It is not for me to say here what this division of labour should be; that must vary with circumstances. In the mansion, as in the cottage, certain work must be done regularly if the home is to be clean and healthy, and it will be all the more likely to be attended to if there is some one person who is responsible for each item.

In trying to arrive at a clear idea of what has to be done to keep a house clean, we shall, perhaps, find it best to take each part of a house, and describe in detail the cleaning necessary to be done daily, weekly, and also at stated periods at longer intervals. Speaking generally, it may be said that daily work must be directed towards the removal of recent surface-dirt, while weekly work and periodical cleaning must aim at a restoration to that condition of perfect cleanliness from which everything around us is in a continual state of departure.

Rooms which are constantly used are more likely to become dusty and dirty than are those which are seldom entered. It is a melancholy fact that we all communicate impurity to material objects by our touch, and even by our presence. We contaminate air by breathing it, and water by touching it. The fire which warms us when we are cold is a very decided source of dirt; the perspiration, which is a sign that we are hot, throws off impurities from our bodies. If we walk out of doors we are sure to bring in with us on boots and clothes some of the dirt from the street. If we could put the contents of the housemaid's dust-pan under a powerful microscope, we should find that a considerable portion of the dust collected there was made up of organic particles—hair, scurf, little pieces of skin, nail-clippings, &c. &c.—the result of the presence of the inhabitants of the house.

The fact may be an unpleasant one, but it is better to recognise it and deal with it than it is to ignore it and leave the ill alone. The only way in which we can turn our knowledge to account is to see that the living-rooms, and the parts of a house which are in regular use, are cleaned *daily.*

Stairs, Halls, and Passages, with the approaches to the house both back and front, should be cleaned early in the day. Before beginning to sweep the hall or the stairs the maid should shut all the doors, that the loose dust may not enter the rooms. Door-mats should be taken up and carried outside of the house, where they should be shaken and beaten with a thin stick. The stairs should then be swept, beginning at the top, and care should be taken to go well into the corners, and to slip out the ends of the rods, in order that dust lying underneath may be removed. Many clever housekeepers, owing to stress of work, have the stairs dusted only every day, and swept once or twice a week. It will, however, be found that if the ends of the rods can be slipped out, and the dust removed from under them frequently, the stairs will not become dusty, and this will save all the house. The sweeper should have what is called a staircase-broom and a dust-pan, with a small round brush for the corners. She should sweep the dust from each stair separately into the dust-pan, and she should try not to make it fly off to settle again on doors and walls.

A long broom will be needed for the hall, and the dust should be swept into one corner, then taken up into the dust-pan. When the dust has had time to settle, but not before, the mats may be laid down again, and the hall may be dusted. (See remarks on Dusting, later.) If brushes are to do any good in cleaning, they must themselves be clean. They should therefore be washed when necessary. They will best keep their shape if hung up, or put away brush upwards. Hair brooms of all kinds will wear longer if put into cold water for an hour when new before being used. The banisters and railings of the stairs, with the doors which open into the hall, must not be forgotten, and all panellings and mouldings and pictures, with the umbrella-stand, must receive attention. The maid should be particularly

careful to remove dust from ledges above her head. When dust is left in these places it flies off and makes the house dirty. If there are any lamps or ornaments in the hall, they must be rubbed and brightened, and handles, or brass knockers, must be thoroughly polished every day in damp weather, three times a week in dry weather.

On a particular day in each week the stair-rods should be taken out, cleaned with a little polishing-paste on flannel, and rubbed well with a leather. Polishing-paste for brass is sold by every chemist, and brass cleaned with it will keep bright longer than if bath-brick is used. Besides, polishing-paste gives a black brightness, but bath-brick gives a white brightness, and the black brightness is to be preferred. When cleaning door-handles it is well to have ready a piece of millboard with a hole in the middle, and to slip this over the handles. It will preserve the paint of the door from being marked with the polish.

Floor-cloths or Oil-cloths should be dusted over every morning with a damp cloth. On a particular day, once a week, they should be washed with a soft clean flannel kept exclusively for the purpose, and cold, or, at any rate, luke-warm water. Neither soap nor soda should ever be used for them, although a little milk may be employed occasionally. After washing they should be rubbed dry with a soft cloth; they will lose their brightness if left wet. *Cocoa-nut matting* should be taken up and shaken once a week. When very dirty it should be scrubbed while down with soap and hot water; then taken up, loosely folded, and dipped into cold water to rinse it, and hung upon a line to dry. *Straw matting* must be fixed or it will crack and not lie flat. It may be washed over once a week with salt and water. *Tiled floors* should be washed in luke-warm water and dried. Sometimes halls are stained and varnished at the edges, and carpet, or matting, is placed in the centre. When this is the case, the boards should be dusted every day, and on a certain day in every week they should be rubbed with a lump of bees-wax and brushed with a furniture-brush.

On the day set apart for washing the oil-cloth, all the windows in the hall should be cleaned. The panels, lintel, and framework of the house-doors also should be dusted one week, and washed, dried, and polished with a leather every alternate week.

At stated intervals—say of three months, and of course at the spring cleaning—the stair-carpets should be taken up and well shaken, and the stairs should be scrubbed down. On these occasions the passage walls should be rubbed over with a Turk's-head broom covered with a soft duster. At the time of the spring cleaning the paper of the walls in the hall should be cleaned like the paper of a room. If the paper is varnished it may be washed with soap and *cold* water and a soft flannel or a sponge. It should be washed and rinsed, then left to dry without being wiped. If an attempt is made to dry it with a cloth, it is sure to show the marks of the cloth.

Bed-rooms.—As it is very important that bed-rooms and beds should be well aired daily, the members of the household should make a point of opening the windows and turning down the beds before they leave their chambers. One great reason why beds are so frequently made without being properly aired is that the housemaid, anxious to get on with her work in the morning, does not allow time for the beds to remain open. The occupants of the room, therefore, should take this business upon themselves, and should open the window top and bottom before

going downstairs. Children even (both boys and girls) might be taught to do this, and they would quickly acquire a habit which would be valuable for the health of the family, and which they would in all probability retain through life.

The beds also should be opened and turned down. Two chairs should be placed at the foot of the bed, and the clothes should be taken off singly and laid upon them, care being taken to keep them from the floor; the bed too should be turned back. Both bed and bed-clothes should then be left exposed to the fresh air for two or three hours. On dry, bright days the beds should be taken into the garden and laid in the sun for a while. In wet weather they should be put before the fire occasionally instead.

So much has been said about the necessity of airing bed-clothes and bedding that it seems superfluous to urge its importance upon the reader. Nevertheless, for the sake of those who may not have realised what it is to sleep in beds which have not been aired, I may repeat the words of Miss Nightingale in her "Notes on Nursing":—

"If you consider that a grown-up man in health exhales by the lungs and skin in the twenty-four hours three pints at least of moisture loaded with matter ready to putrefy; that in sickness the quantity is often greatly increased, the quality is always more hurtful, just ask yourself next where does all this moisture go to? Chiefly into the bedding, because it cannot go anywhere else. And it stays there; because, except perhaps a weekly change of sheets, scarcely any other airing is attempted. People are careful to fidgetiness about airing the clean sheets from clean damp, but airing the dirty sheets from dirty damp never even occurs to them.

"My heart always sinks within me when I hear the good housewife of every class say, 'I assure you the bed has been well slept in;' and one can only hope it is not true. 'What? is the bed already saturated with somebody else's damp before its next occupant comes to exhale into it his own damp? Has it not had a single chance of being aired?' 'No, not one. It has been slept in every night.'"

It will be seen, therefore, that the object of airing beds is to free the bed from the dampness caused by the perspiration of those who have slept in it, and to purify it by letting fresh air blow upon it. It is evident, however, that it is no use to keep the window open in damp, foggy weather. Judgment should be exercised about airing a room as about everything else. On damp days the window should be opened for a little while only to let in fresh air, and to purify the atmosphere; on foggy days it should not be opened at all. Every day the lower sash should be closed at sunset.

Emptying Slops.—On going upstairs to "do" the bed-rooms, the housemaid should take with her a slop-pail and a little hot water in which a lump of soda has been dissolved, and two dry cloths (one for the chambers, one for the basins). One word may be said about the care of the slop-pail. Of course it should be kept exclusively for its purpose; after use it should be scalded and wiped dry inside and outside, and when not in use should be put somewhere where the air can get to it. The lid should be scalded and wiped, as well as the pail, and, when not in use, should be hung above it, not placed upon it. Twice a week both pail and lid should be washed with chloride of lime and water.

The chamber ware should be scalded daily with hot water, and wiped dry with the soft cloth kept for the purpose. This cloth should be rinsed in hot water and

soda after being used, and hung in the air to dry. If chambers are scalded and wiped out daily, there will be no fear of their becoming furred. Should it happen through neglect that they get into this condition, strong soda and water must be put into them and left for some hours, and if this does not remove the deposit the utensils may be scoured with a mixture of Calais sand and salt. There is very little "fixed dirt" in this world which will stand against vigorous scrubbing with sand and salt, and I should think there is no dirt at all which will stand against sand and salt with a little vinegar added.

Beds and Bedding.—The slops should be emptied in all the bed-rooms before the beds are made—first, because this will allow the beds to be left open longer; and, secondly, because the housemaid should wash her hands and put on a clean apron before making the beds. Mattresses and beds should be turned every day from head to foot. If there is a feather bed it should be shaken vigorously, and any lumps there may be in it should be rubbed out. The bed-clothes should then be put on it. The under blanket should be laid on first, then the bolster, which must be well shaken, then the under sheet. The pillows also should be shaken, and they should be placed with the outer part of the pillow-case to the edges of the bed. When putting on the upper sheet the housemaid should remember to keep that end to the top which will leave the hem folded under when the bed is turned down, and also to tuck in each sheet and blanket separately, not all at once. Unless this is done the under bed-clothes drag when the upper bed-clothes are turned down. To make a bed properly is a by no means ordinary accomplishment. People who are not naturally sound sleepers, and who have been compelled to lie in beds made by inexperienced housemaids, will testify to the truth of this statement.

Beds and mattresses should be covered entirely with common calico. The covers should be so made that they can be removed, and washed and replaced once a year. Some people have strips of calico, and sew these on the edge of the mattress, but it is much cleaner to cover it entirely. Every week the blankets and coverlets should be shaken; both bed and mattress should be brushed all over, lifted off, and the framework of the bed should be dusted, the joints and crevices examined, and curtains and bed-furniture, if there be any, shaken and brushed. Before laying the mattresses in their places strips of canvas, or strong brown paper, should be laid between the iron framework and the ticking; these must be brushed or shaken every week.

Bed-linen must be changed frequently; the oftener this can be done the better. Clean linen is a luxury as well as a necessity, but the extent to which it can be enjoyed must be determined in many households by the supply, and also by the possibilities connected with laundry arrangements. If it is at all practicable sheets and pillow-cases should be changed every week, on a stated day. When this cannot be done, fresh sheets must be allowed every fortnight. One clean sheet should be put on the bed every week; it should be placed at the top, and on each occasion the top sheet should be put to the bottom, and the bottom sheet taken to the wash. Some people like to use calico for the under sheets, for the sake of the warmth, and linen for the upper sheets, for appearance sake, and for coolness. When this is the case the method of putting on a clean upper sheet only could not of course be followed.

Bugs.—When beds and bed-rooms are kept clean and are thoroughly ventilated,

there is not the slightest fear of annoyance from bugs. If, however, through neglect these insect pests do effect a lodgment, vigorous steps must be taken to eradicate them. The bed must be taken to pieces at once, and any wanderers which can be captured, as well as the nits or eggs of the insects, must be destroyed. The framework of the bed must be washed with chloride of lime and water, and Keating's insect-powder must be sprinkled into all the joints, cracks, and crevices. After this is done, the bed, mattress, and framework must be carefully looked over every day, and, if necessary, the bed must be taken to pieces a second time and the process repeated.

Fleas may be got rid of by washing the bedstead and the floor of the bed-room daily with either strong salt and water or chloride of lime and water.

Blankets must either be washed or sent to the cleaner's every spring. Very great care must be taken to air them thoroughly after washing. Each blanket should be hung two days in the fresh air and one day before the fire.

After the bed is made, the "pieces" may be taken up in a dust-pan, the room may be thoroughly dusted, the jugs may be filled with water, and the caraffe with filtered water, and the room is finished.

When all the bed-rooms in the house are finished, and the door of each is shut, the stairs may be dusted.

Dusting.—There is a right way and a wrong way even of dusting a room or furniture. In order to do the work properly, it will be necessary to have a clean soft duster, or a damp leather, and a furniture-brush. A damp chamois leather is the best of dusters, especially for black woods. Dusters may be bought of the drapers, or they may be made of old cotton dresses, old sheets, or old chintz covers of any kind. Old chintz makes capital dusters. Whatever the material used, the dusters should be hemmed, for that will make them wear longer; also they should be whole: if ragged and torn, small ornaments will be likely to catch in them and be broken. The housemaid should begin at one end of the room and go round, carefully dusting every article, until the circuit of the room has been made. Neither ledges, panels, the framework of the door, nor the legs of chairs and tables should be omitted. Looking-glasses should be polished. Carved ornamented parts should have the dust removed with the furniture-brush. In dusting the dressing-table or the mantelpiece, ornaments should be lifted off entirely, then dusted separately, and put back again when their place is made ready for them.

Care should be taken to *take up* the dust with the duster gently and carefully, and to get rid of it by shaking the latter frequently out of the window. Miss Nightingale says:—"No particle of dust is ever, or can ever, be removed or really got rid of by the present way of dusting. Dusting in these days means nothing but flapping the dust from one part of a room to another, with doors and windows closed. What you do it for I cannot think. You had much better leave the dust alone, if you are not going to take it away altogether; for, from the time a room begins to be a room up to the time when it ceases to be one, no one atom of dust can ever actually leave it thus. To 'dust,' as it is now practised, really means to distribute dust more equally over a room." Miss Nightingale says also that the only effectual way of removing dust is to wipe everything with a damp cloth. This cannot be done with polished furniture, but, at any rate, it would be possible to rub it a little every time it is dusted.

Polished floors must be dusted every day. If there is no carpet under the bed, the boards there should be wiped over with a damp cloth every day.

Weekly Cleaning of Rooms.—A certain day in each week should be fixed for sweeping each bed-room in the house, and the weekly brushing of the bedstead, mattresses, and bed-furniture may be attended to at the same time. This examination of the bedstead should be done by two persons, and a careful scrutiny should be made of every part, especially of the joints of the bed and the folds of the braid. The examination should be particularly searching in spring. At this season all beds should be taken entirely to pieces, for it is then that insect pests wake from the dormant condition in which they exist during the winter. Mattresses and beds should then be carried into the open air and beaten well, then exposed to the sun for a while. If there are any traces of intruders, the joints and cracks should be thoroughly washed with chloride of lime, and insect-powder should be sprinkled over them.

In very bad cases, where insects appear to have made a home in a bed, both bed and mattress must be taken entirely to pieces, then placed in a room made quite air-tight, and subjected to the fumes of burning sulphur. A red-hot brick is placed upon a tin, put into the middle of the room. A little sulphur is laid upon the heated part. The operator then goes from the room as quickly as possible, closes the door tightly, and leaves it for a couple of hours. At the end of the time the windows may be opened, and the business may be regarded as complete. It is in this way that furniture-brokers deal with articles of furniture supposed to be infested with insects.

Sometimes it happens that bugs get into walls and cupboards, and then they are very difficult to dislodge. A constant look-out for them must be kept up, and if this is not sufficient, the room must be subjected to the action of sulphur fumes, as the beds and mattresses were. A very effectual means of getting rid of these nuisances is to oil-paint the walls.

After a bed has undergone the weekly examination, the blankets should be shaken, the bed made, the curtains (if there be any) and the vallances pinned up, and the bed and chamber-ware covered with a dust-sheet. The blinds should then be drawn up, the windows closed, to prevent the dust flying about, the dresses, ornaments, and all small articles put away, the drawers and cupboards shut closely, and toilet-covers, &c., shaken and folded. The hearth-rug also should be taken up and carried out of doors, where it may be beaten with a thin stick before it is laid down again. Carpet-beaters are also sold for purposes of this sort. They operate upon a much larger surface than a stick could possibly do.

When the room is thus prepared, the range and fire-irons should be cleaned. Before this is done, however—and, indeed, before a fire is done up at any time—care should be taken to lay in the front of the hearth a piece of coarse canvas, or drugget, kept for the purpose, and intended to preserve the carpet from contact with black-lead brushes and fire-irons. The fender and fire-irons also must be lifted away, and the hearth swept thoroughly. The ashes, if there be any, should be raked out of the corners and put into a scuttle, to be afterwards sifted, when the cinders may be burnt and the dust thrown away. A long sweep's brush should also be put up the chimney, as far as the hand can reach, to sweep away the loose soot. It is important that the flue should be left open for the purpose of ventilating the

room, and if the chimney is thus swept regularly, the hearth may be kept tidy, even in windy weather.

Black-lead, moistened with water, should now be put lightly on the range by means of the small round brush kept for the purpose. Very little black-lead should be put on at one time, for the polish is to be obtained by brisk rubbing rather than by a large quantity of black-lead. When a range is in good condition, the constant employment of wet black-lead may be avoided, and it may be polished by being brushed briskly with a brush upon which a cake of dry black-lead has been rubbed. If wet black-lead is used, it should be polished *before* it is dry, not afterwards. An idea is prevalent, that black polishes such as blacking and black-lead should be allowed to dry before being brushed. This is a mistake. It is less labour to polish when dry, a better effect is produced by polishing instantly.

Tea-leaves, which have been washed and drained, should now be sprinkled over the carpet, and the latter should be well swept with a good, hard, short brush, the sweeper going down on her knees to her work, and being careful to remove dust from under the bed, and to move out all furniture which can be moved. She should begin at the far end of the room, and sweep towards the door; and, as soon as the dust is collected in one place, she should take it up in the dust-pan and carry it straight away, not leave it to be knocked over by the first passer, and trodden about the room again. The carpet will look much brighter if it is rubbed all over with a damp but not wet cloth after being swept. It should be remembered that unwashed tea-leaves are likely to stain the carpet instead of brightening it. Also that experienced housemaids are careful to tie a handkerchief over their heads while sweeping, in order to preserve their hair from dust which may settle on it.

Dust must be allowed to settle before an attempt is made to remove it. When it is ready, however, the housemaid should begin at the far end of the room, and go all round, carefully taking up the dust as she goes, according to Miss Nightingale's directions, not flapping it off to let it settle in another place. She must carefully mount up and dust shelves and ledges above her head; the framework of the doors and windows must also receive attention from her. If the room is furnished with a Venetian blind, the housemaid should get the house-steps, mount them, and dust every lath separately on both sides, pulling the cloth under the tapes and round the cords. Some housemaids let the blind down, then take a clean broom, and sweep down the blinds. By this means they break the tapes, besides leaving a line of dust at the back of the laths where the broom does not reach. Venetian blinds dusted regularly and carefully will last twice as long as they will when brushed down with a broom.

Of course, the chamber-ware must be well washed in warm soap and water, and dried with a soft towel. The water-bottle should be taken downstairs and washed. A handful of salt and a little vinegar, or a spoonful of turpentine with water, and a brush, may be employed. The bottle may then be dried, polished with a leather, filled with filtered water, and taken back again.

Gas Globes and Brackets are frequently omitted in cleaning a room. The bracket should be dusted daily, and when dirty should (if made of bronze or lacquered brass) be washed with soap and water, the green greasy part near the burner being rubbed with a rag dipped in equal parts of stale beer and vinegar. Globes should be washed well every week with luke-warm water, soap, and soda. They should drain well till

almost dry, then be dried with a cloth and polished with a leather. China ornaments of all kinds belonging to the bed-room may be washed in the same way, the ornamental parts being brushed with an old nail-brush. A brush should be specially kept for this purpose, or careless housemaids will be sure to use the one which is in the brush-tray. When the carpet does not cover the room entirely, the boards under the bed should be wiped with a damp cloth, which may be used also for wiping the carpet occasionally.

Bed-room Windows should be cleaned on a certain day every fortnight. A time must be chosen when the sun is not on them, otherwise they will be shaded when dry. They should be rubbed with a leather wrung tightly out of clean cold water, then polished with a soft dry cloth. Every time the windows are cleaned the window-sill should be washed well with flannel and soap and water. Looking-glasses should be cleaned with a sponge dipped in spirits of wine and polished with a leather, or with a soft cloth dipped in powdered blue.

Polished furniture needs to be attended to regularly, if it is to be kept in good condition. A good furniture-cream may be procured by boiling 2 oz. of soft soap with 1 oz. of pearlash, 8 oz. of bees'-wax, and two quarts of water, till the ingredients are melted and mixed. The cream should not be used till cold. Care should be taken to use a small quantity only of furniture-polish. Elbow-grease is needed more than polishing-paste to brighten furniture, and the latter should do no more than furnish an excuse for a liberal application of the former. A great deal may be done in the way of keeping furniture bright by acquiring a habit of giving it a *good* rub every time it is dusted. Many good housekeepers object to use furniture-cream. They prefer to wash the furniture twice a year with cold tea, or weak vinegar and water, and to rub it well once a week with a damp leather and soft cloth.

Baths should be cleaned once a fortnight. They are apt to become dark-coloured inside with use. This discoloration may be removed by rubbing the part with a wet flannel dipped in salt.

Sponges should be squeezed as dry as possible each time they are used. Unless care be taken with them, and especially if soap be used for them, they are apt to get slimy. If this condition should be reached, the sponge should be laid for several hours in strong soda-water, which soda-water should be changed frequently, the sponge at the same time being pressed and squeezed in the centre. If, after being thus cleansed, the sponge is laid for some hours in a mixture made of one glassful of muriatic acid and three pints of water, it will be almost as good as new. Sponges are better for being dried in the sun after use.

Combs and Brushes should be cleansed together on a certain day in each week. Brushes may without injury be washed in warm soda and water, if care be taken to prevent the water touching the back of the brush. They should not be rubbed, but should be dabbed up and down in the water, being held by the handle till perfectly clean, rinsed thoroughly, and two or three times, in plenty of cold water, then laid in the open air or away from the fire to dry. Where soda is objected to, a little carbonate of ammonia or borax dissolved in water may be used instead. If brushes are washed constantly, combs need not be washed at all, and will never require it. Water takes the polish off the comb, warps the material, and makes the teeth split. Combs can be cleansed perfectly by being brushed well, either with an

ordinary brush or with a small brush sold for the purpose, upon which either flour or violet-powder has been sprinkled.

When all these points have been attended to, and the room is finished, the blind should be let down one-third of the way and put straight, the jugs should be filled, and the door closed.

At the time of the spring cleaning, and also in autumn, bed-rooms will require further attention. At this period each article of furniture should be cleaned in the room, then carried out of it; drawers should be emptied and scrubbed out, then lined with clean papers, and, as is too frequently the case, the framework behind the drawers should not be forgotten. Cupboards should be emptied and cleaned; pictures taken down, the frames brushed and the glass cleaned; ornaments washed, &c. When everything that can be moved has been taken out of the apartment, the furniture which remains should be covered entirely, and the chimney should be swept; the soot should be cleared away, and the room swept once more. The ceiling may then be whitewashed, and the room papered and painted, if this work is considered desirable. (It has already been said that beds must be taken to pieces at the time of the spring cleaning.)

It is very desirable that ceilings should be whitewashed, or, better still, re-papered, frequently, every year if possible. This will be by many considered unnecessary, at any rate so far as the bed-rooms are concerned. When professional whitewashers are engaged, the business is both troublesome and expensive, and housekeepers usually defer it as long as possible. Yet nothing tends more to make a room sweet than fresh clean ceilings. The impure air in a room rises to the surface, and the ceiling deteriorates in condition more quickly than any other part.

Whitewashing, as ordinarily executed, is not to be recommended from a health point of view. The method generally adopted with regard to it is to dissolve whiting in water, to make a liquid of the consistency of cream. To this preparation a small portion of melted size or glue is added to fix the material, and to keep it from falling off. It is this size which is objectionable. Size is made from the bones and skins of animals, and, like all organic matter, it is certain to decompose with time, thus rendering the atmosphere impure. When whitewash is used, the ceilings should be well washed in the first instance with clean water to remove the dirt, and the preparation should be put on lightly and evenly with a broad, flat brush, worked in straight lines.

Papered or glazed ceilings are, however, to be preferred to whitewash. Glazed and painted surfaces do not absorb dirt as do unglazed ones, and they can be washed when necessary with soap and water. The same remarks apply to walls. These are never so pure as when oil-painted. Next to painting, papering is to be recommended.

When, as is usually the case, walls are papered, they must receive special attention at the time of the spring cleaning. The best thing that can be done when neither whitewashing, limewashing, nor papering are considered necessary, is to take a long broom, fasten a duster securely on it, and dust both ceiling and walls thoroughly, going well into the corners, and taking off all loose dust. A stiff and quite dry dough of coarse flour and water should now be made, the cleaner should mount the steps and rub the wall all over with the dough, downwards only, not upwards, and taking about half a yard at a stroke. After going once round

the room, he should begin again a little above where the last line ended, and repeat until the entire surface has been gone over. The paper will, if not very dirty, look almost as fresh as when new.

When it is determined to re-paper a room, the old paper should be stripped off entirely before operations are commenced. Thus only will the work be effectually done.

Grease-marks may occasionally, but not always, be removed from wall-papers by laying a little moist fuller's earth on the spot and leaving it till dry, then taking it off with a brush. When this plan is not effectual, the dirty paper should be torn off the wall and replaced by a new piece, care being taken to match the pattern and lines. When a room is newly papered, a portion of paper should always be put away to be used on occasions of this kind.

When walls and ceilings have been dealt with, the paint is the next point to be considered in cleaning a room. *Paint* needs very careful washing. It should not be scrubbed, but first dusted, then thoroughly washed all over with a soft flannel, soap, and water, and dried and polished with a leather. If varnished, cold water only should be used, although, if unvarnished, luke-warm water and a very small piece of soda may be allowed. The flannel should be well wrung, then soaped; if too wet the drippings will run down and leave their mark on the paint. A small portion should be taken at one time, and this should be rubbed gently and patiently backwards and forwards with the flannel until clean, when it should be rinsed clean and dried, when the next portion may be proceeded with. If this simple method is adopted, the paint will be quite clean, and need not be injured at all. It is so obvious that it appears like waste of words to describe it, and yet it needs an experienced person to wash paint properly. Inexperienced persons make large preparations. They get hot water with soap and soda, operate energetically on a large surface at once, and splash away, and at the end of all are sure to spoil either paper or paint.

Particular care is necessary in washing wainscoats, for careless cleaners often go above the paint and touch the paper with the flannel, and this quite spoils the look of a room. Window-frames and mouldings in painted woodwork should be very carefully washed, because it is in places of this kind that insects lay their eggs, which washing will destroy. The reason why so many houses are besieged by flies is frequently to be found in the fact that the paint was not washed properly in the early spring. The paint in a house should be washed at least twice a year. Dark paints are now a good deal used for rooms, and it must be remembered that they become as dirty as light paints in the same space of time, although they do not show the dirt so much.

The Floor is the next consideration. If this is stained and varnished it will need only to be washed over with cold water (to remove stains, &c.), then rubbed with bees'-wax, and polished with a furniture-brush. When it is necessary to renew the polish of the floor, a mixture of copal varnish and Brunswick black may be employed. The proportions used must, of course, depend upon the depth of colour desired. The deeper the colour, the more Brunswick black. If the mixture should appear too thick, a little turpentine may be put with it to thin it. If the floor is not stained, it must be scrubbed. The cleaner should begin at the far end of the room, taking a position from which she can work up and down the boards, but never across the grain. She should first wash a little piece of flooring, as much as her hand can reach easily

with flannel and warm water, then rub soft soap on her brush, sprinkle a little coarse sand on the boards, and scrub until the boards are quite clean. However vigorously she may have worked, she will so far have done nothing but remove the surface dirt, and *loosened* the fixed dirt. If she were to let the floor dry now it would be as dirty as ever; she must rinse it well to take up the dirt which has been loosened by scrubbing; rinsing is, therefore, almost more important than scrubbing. After rinsing two or three times, she should rub the floor dry with a cloth, and proceed to the next portion. It has been already said that the chandelier should be cleaned with beer and vinegar. The globes also should be washed as already directed.

A carpet is a wonderful preserver of dirt and dust. Let any one who doubts this have a large carpet (of the kind usually taken up once a year) shaken and beaten by a most competent person and laid down again, then at once swept with a broom. It will be found that the dust flies and can be swept up still. There would be much less dirt in our homes than there is now if carpets could be altogether dispensed with. Miss Nightingale says:—"A dirty carpet literally infects the room. And if you consider the enormous quantity of organic matter from the feet of people coming in, which must saturate it, this is by no means surprising." It would be well if where carpets are used they could be taken up three times a year instead of once, but few housekeepers would care to have this trouble. When a carpet is taken up, it should be beaten with sticks, then shaken and beaten and shaken again, until no more dust comes from it. It should then be dragged upon grass several times, backwards and forwards, to freshen it and brighten the colours, and when all this is done it may be laid down again. As already said, if it is at once swept with tea-leaves a little dust may be taken from it.

When very dirty, a carpet should either be sent to the cleaner's or washed with bullock's gall, to be obtained of the butcher. It should first be shaken and beaten well, and stretched and fastened down in its place. A mixture should then be made of three parts of cold water to one part of bullock's gall, and the carpet should be washed with this and a clean flannel, brushed with a soft brush and rubbed again with the flannel, then left to dry while down. Bullock's gall cleans carpets very well, but they quickly become dirty again after it has been used. Ink-stains can usually be entirely removed if attended to immediately. The ink should be taken up with a spoon, and blotting-paper pressed upon the part until no more ink can be absorbed. The place may then be washed if necessary. Old ink-stains are not easily removed. Occasionally they will yield on the application of salts of sorrel to the spot, which has been previously moistened. The salts must be washed off as quickly as possible.

While the floor is drying the windows may be cleaned. It is to be expected that they will be particularly dirty, being marked with soap and water used in washing the window-frames. If the room has been painted and the window-panes have been inadvertently splashed with paint, these splashes may generally be removed with strong soda and water, or they may be scratched off with the edge of a penny.

The mantelshelf will be washed at the same time as the paint. If it is of marble and is in good condition there can be nothing better for it than soap and water. If very dirty, a stiff paste may be made with soft soap, caustic potash lye, and whiting. This should be spread upon the marble and allowed to remain for a

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while, then taken off, when the marble can be washed with soap and water. If little pieces are chipped off marble they may be mended with plaster of Paris, moistened with water to make a stiff paste. The preparation must be used quickly, for it will speedily harden. Care should be taken to avoid stains on marble, as these are not easily removed.

The furniture of the room may now be brought back to its place and polished. Pictures may be hung again, and ornaments restored to their places. It is supposed that at the time of the spring cleaning light summer curtains will take the place of the heavy ones which are suited for winter. Putting appearance on one side altogether, it is a mistake, from any economical standpoint, to keep heavy curtains up during the summer. They are more costly than summer ones, and they last more than twice as long if taken down as soon as the sun's rays begin to be powerful, brushed thoroughly, and laid away with dry bran sprinkled between the folds. With regard both to carpets and curtains, it will be found that there is no greater destroyer of fabric than dirt. Articles which are kept clean and free from dust wear longer as well as look better.

Sitting-rooms, drawing-rooms, dining-rooms, and parlours should undergo very much the same treatment as bed-rooms. In both cases curtains and ornaments should be cleaned and put away, the chimney swept, the ceiling white-washed, the walls cleaned, paint washed, floors scrubbed, chandeliers polished, and blinds looked after.

Venetian Blinds should, unless they have been recently painted, be washed with cold water and soap at the time of the spring cleaning. The tape which is fastened under the lowest lath should be loosened, and the knot found under it should be unfastened; the cord can then be drawn up and the laths slipped out one by one, washed thoroughly and separately, and polished with a leather. If liked, the tapes also can be washed and ironed, but it will be found that this is rather troublesome work for inexperienced hands. When slipping the laths in again, care should be taken to put the narrow tapes first on one side of the cord and then on the other, or the blind will not hang properly.

Stuffed Seats of Chairs or Ottomans, Sofa Pillows, and Footstools should be thoroughly beaten to get the dust from them at time of the spring cleaning. They may be beaten with a cane, or better still by a beater, and care must be taken not to split the fabric when doing the business.

Books are very troublesome articles for holding dust, and if not kept clean they will be spoilt, for dirt is a dreadful destroyer. Where there are a great many books, it is often found convenient to clean one shelf at a time, continuing the business as opportunity occurs until all are done. All the books on a shelf should be lifted down and beaten first singly and then in pairs, and afterwards dusted all over. The edges of the leaves, especially at the top, should then be brushed with a soft clothes-brush. The shelves should be washed and allowed to dry thoroughly before the books are put in their places again, otherwise the damp wood may cause them to become mouldy. It is a great protection where books are not kept under glass to have leather nailed upon the edges of the shelves to keep the dust from the tops of the books. Dust-sheets should always be put over books while a room is being swept.

Lamps. The excellence of the light obtained from lamps depends largely upon

their being kept perfectly clean. If little pieces of wick, ends of lucifer-matches, or burnt paper fall into the lamp, and especially if encrustations are allowed to collect inside its upper portion, the light is sure to be a poor one. Moderator lamps should every day be filled with oil. The wick should be cut evenly with a pair of scissors kept for the purpose, and the lamp itself should then be wiped with a rag. The inside of the chimney should be cleaned with a stick covered with wash-leather pads. If attended to thus every day, the chimney will never need to be washed. and this is an advantage, as it cracks easily when hot, after it has once been made wet. The globe of a lamp may be cleaned like a gas-globe. Wicks are more likely to burn if dried in the oven before being put in. It is important that the oil-can should be kept clean as well as the lamp itself, otherwise the purity of the oil and consequently the efficiency of the lamp will be interfered with. The can should be emptied occasionally, wiped out inside with a mop, and rinsed well with strong soda-water, and drained till dry. The method of cleaning the outside of ornamental lamps must vary with the material to be dealt with.

Brass may be cleaned with oil and rotten-stone, or with oxalic acid.

Lacquered Work may be dusted with a soft cloth and washed occasionally with luke-warm water, soap, and flannel; in order to prevent smears, dust a little flour over and polish with a cloth.

Bronze should be wiped with a cloth or dusted with a soft brush. Articles of this description should not be touched with wet cloths. Bronze lamps, however, are not to be recommended, because the oil oozes through the metal, as it does also through glass.

Gilt Lamps should be dusted, and washed when necessary with soap and luke-warm water and polished with a leather.

China Lamps may be washed with soap and water.

The stickiness which is found on colza lamps is best removed by paraffin, a most valuable cleansing-medium.

Lamps should be emptied out and cleansed occasionally. When this is done they should be dried before being refilled. When kerosene is used the lamps will sometimes smoke, give a bad light, and smell. When this is the case the burners should be put into an old saucepan with water, and a table-spoonful of soda, and boiled for half an hour, then wiped dry.

The keys of a piano should be cleansed thoroughly and frequently with a damp but not over wet cloth or leather. If made too moist the pads which are under the keys will swell, and thus make the keys stick.

To clean Ormolu Ornaments.—As a rule, ormolu should be rubbed with a dry leather and nothing else. When it begins to look shabby it requires the attention of the manufacturer. Sal volatile is sometimes used for cleaning it, but it is not satisfactory, because the ornaments tarnish quickly after it has been employed. Some people rub the ornaments well with whiting moistened with gin, brush off with a very soft brush, and polish with a leather. Great care is required in doing this.

To clean Terra Cotta.— Brush the terra cotta with a good soap lather and a soft brush, rinse in cold water, and dry without wiping.

To remove Grease from Silk or Stuff.—Lay a sheet of thick soft brown paper over the spot, pass a hot iron quickly over it, and lift the paper instantly. The heat will melt the grease and draw it into the paper.

To remove Paint-spots.—Rub quickly from the circumference to the centre, first with a sponge dipped in turpentine, afterwards with a soft cloth.

To remove Red Ink-stains from Linen.—Squeeze the juice of a lemon upon the place and rinse in milk. Ink, wine, and many other stains may be frequently removed by soaking the material in milk and rubbing and pressing it for a while. The milk may be renewed two or three times if necessary.

Port Wine Stains may be taken out with Sherry. Fruit-stains will usually disappear if the spot be rubbed with a weak solution of ammonia.

To clean Japanned Trays, etc.—Wash with soap and warm water, sprinkle flour on, and polish.

Papier Maché Goods.—Wash with cold water and no soap, dredge with flour and polish.

Gold Chains, Earrings, Ornaments, &c.—Cleanse these in soap and water with a soft tooth-brush. Lay them while wet in boxwood sawdust, leave them for two or three hours, and they will come out dry and looking like new. Boxwood sawdust can be procured at the wood-engraver's. If it cannot be obtained, bran may be employed instead, but it will not answer its purpose so well.

Silver Ornaments.—Clean with a paste made of whiting and gin, and polish with a leather.

Rust.—To remove rust from polished iron or steel rub first with sweet oil, and in a couple of days with quick lime finely pulverised; or with a paste made of fine emery and sweet oil; or, chemically, with a mixture of polishers' putty-powder and a little oxalic acid applied with water. When the last is used all trace of the acid should be removed by washing the article in water and drying it thoroughly with a warm cloth. Iron or steel fenders may be kept from rusting by preserving them perfectly from damp. Recently-polished steel may be kept in good condition for a long time by simply rubbing it over very frequently, every day in dry weather, twice a day in damp weather, with a warm dry duster.

Gilt Frames should be brushed only, not washed. If they are spotted with fly-marks they may be rubbed gently with a cloth dipped in vinegar and water. This spoils the gilt less than plain water, or soap and water. If they become tarnished they may be brushed over with Judson's Gold Paint.

Steel Ornaments.—Rub with a paste made of French chalk and spirits of wine, and brush off when dry. Steel brooches and earrings should be kept in a box filled with arrowroot to prevent rust.

Moths.—All woollen goods should be examined and aired frequently if moths are to be kept away. Strongly-scented articles, such as Russian leather, cedar-wood, or tobacco-leaves, should always be placed in the box or drawers with the flannels or furs, in order to prevent the ravages of these destructive insects. If moth should get into the carpet, the latter should be taken up, beaten and examined, and any grubs there may be should be destroyed. The carpet should then be rubbed on the wrong side with carbolic soap, and Keating's insect-powder should be sprinkled over the parts attacked. If moths should effect a lodgment in furniture they can only be got rid of by sending the articles to the upholsterer's to be stoved.

Water-closets need constant attention. Every morning the housemaid should pour down three or four pailfuls of water; she should also hold the plug up as high as it will go for three or four minutes, and clean the pan with the round brush kept for the purpose. If through neglect of this necessary work a deposit should have formed on the lower part of the pan it must be scoured thoroughly with a mixture of sand and salt. Unless this is done the deposit will become fixed on the vessel, and this will be very disgraceful. The condition of the water-closet is a more certain sign of the character of a housekeeper than is any other part of the house, the back-kitchen and larder alone excepted. If these three places are fresh, clean, and bright, there need not be much question about the rest of the habitation. The handle and the plug in a water-closet are often made of brass. They should, then, be polished like the handles of the hall doors and at the same time. It is a good plan to keep either carbolic powder or a bottle of diluted Condy's fluid in the water-closet, and to use this every morning. The window of the apartment should, however, be kept open all day long, for fresh air is worth more than all the disinfectants that ever were invented.

KITCHEN AND OFFICES.

The kitchen is often the part of the house which is most neglected both by builders, housekeepers, and servants; and it is frequently found that, though the rest of the house is tastefully and elegantly furnished, the kitchen is deficient in ventilation, arrangement of detail, and size. This is unfortunate, for if there is a part of the house which needs for convenience, health, and comfort to be cleaned, ventilated, and cared for more than another, it is the room where large fires must be kept up, and where the work of preparing food is carried on. The air of a kitchen affects the condition and health not only of the people who live in it, but of the food that is cooked in it; and we cannot expect that a family can be supplied with wholesome nourishing food if this be kept in a dirty larder and cooked in a badly-ventilated, dirty kitchen.

Following the plan already adopted, it will be well to describe the daily and the periodical work of a kitchen (so far, that is, as cleaning only is concerned).

Open ranges are a fruitful source of dust and dirt in a kitchen. They are now less common than they used to be, and have been largely superseded by closed ranges and gas stoves. The mode of cleaning is determined by the construction of a range. In all cases where there has been a fire, the first thing to be done every morning is to clean out of the range all ashes and cinders; sift these, reserve the cinders for use, and throw the dust away. As much of the soot as can be reached in chimney and flues should then be swept away with a sweep's brush kept for the purpose, and when this is done the range may be black-leaded. In houses where one or two servants only are kept it will, perhaps, be deemed sufficient if the bars and front of the fire only are black-leaded every day, the whole of the range being dealt with on a fixed day twice a week. Where there are several servants, the range flues should be swept out and black-leaded, and the oven scraped and washed every day. The process of black-leading a range has been already described in speaking of the work in a bed-room. The method is the same in a kitchen range, the difference being that there are flues, and drawers, dampers, and various arrangements in the latter case which do not belong to the former. If grease is spilt upon either an open

or a closed range, it should be washed clean with a flannel, hot water, and soda, and wiped dry before it is black-leaded.

An oven needs special attention in cleaning, because liquid food cooked in it is so liable to flow over the sides of the vessel containing it, and to burn and soil the shelves. An oven should in all cases be swept out thoroughly every day. When the range is black-leaded the oven shelves should be scraped with an old knife, then washed in vinegar and water. This helps to make them sweet and fresh.

Gas stoves should (after the bars have been lifted out and rubbed with emery) be washed free from grease and dust with hot soda-water, and dried well. After this it may be black-leaded in the usual way.

Steel-work in a range should be cleaned by being rubbed with emery-paper. Crocus-powder, to be bought of any chemist, is, perhaps, the best thing which can be employed for cleaning steel. A very small quantity should be mixed with sweet oil and laid on, to be rubbed off when dry, and polished with a leather and a little dry powder. Brass-work, such as boiler-taps, knobs, and bolts, should be cleaned with polishing-paste and a leather. Oxalic acid (poison), an ounce to a pint of water, is very good for cleaning brass. If very dirty it may be rubbed afterwards with crocus-powder. All brass and steel work in a kitchen should be kept bright and shining. The general aspect of the place depends greatly upon this being done.

The kitchen hearth should be washed over with a house-flannel and clear water. The cloth should then be wrung out of the water again, and the hearth should be whitened with a flannel dipped in whiting moistened with a little milk and passed evenly backwards and forwards, until the surface has been gone over. Whiting mixed with milk does not come off so easily as when moistened with water.

Kitchen Fenders and Fire-irons should be cleaned with emery-paper, or with a flannel dipped in warm ash-dust.

Boilers should be washed out thoroughly inside every week, and if any fur collects on the side it should be scraped off. An oyster-shell may be kept in a boiler, as in a kettle, to prevent fur.

Kitchen utensils of all kinds—saucepans, tins, plates, dishes, knives and forks, spoons, and glass—should be cleaned as soon as possible after they are used, because newly-made dirt comes off more easily than dirt which has had time to dry and become hard. Pans which cannot be cleaned at once should be filled with cold water until they can be attended to. It should always be remembered that plenty of clean water is essential for thorough cleaning; a small quantity of water, or a continued use of the same water for a number of utensils, increases labour and hinders cleanliness.

Soda cannot be dispensed with in removing grease, for soda has an affinity for grease, and will mix with it whenever it comes in contact with it. It is the soda contained in soap which makes soap so cleansing. Nevertheless, soap should not be used for wooden articles which have to be used for food, because the wood sucks in the soap, which is not easily eradicated, while it is not agreeable to eat food which contains even a suspicion of soap. Metal articles may be cleansed with a little soap if necessary, because the soap cannot sink into the metal. It may be useful, however, to go

still further into details with regard to the method of cleansing various kitchen utensils.

Copper Pans.—Wash the pan well inside and out with hot water and soda. Mix equal quantities of Calais sand and salt in a plate. Clean the inside of the pan first with sand, salt, and soap until all stains are removed; rinse it well with hot water, and dry it. Clean the outside with salt and sand, and if there are any stains upon it remove these with a squeezed lemon-skin rubbed with soap and dipped in sand and salt. The lids of saucepans should be cleaned like the saucepans themselves. Rinse and dry quickly. The outside of the saucepan should be thus cleaned with acid.

Iron Pans.—Wash the saucepan inside and out with soda and hot water. Clean the inside with sand by means either of a flannel or a mop, or bundle of twigs tied tightly together and cut straight. Rinse with hot water and dry quickly. Lids of saucepans should also be washed in hot water and soda, and rinsed well. Saucepans should never be put away covered; they should be placed upside down on a rail, and the lids should be hung above them so that the air can enter freely. If covered closely they will get fusty. Saucepans should always be emptied as soon as done with, and filled with cold water until they can be cleaned.

Enamelled Pans may be cleaned inside and out with hot water and soda. Stains from the enamel may be removed with salt and sand.

Tins should be washed clean with hot water and soda. To brighten tin rub first with a paste of whiting and water, afterwards with dry whiting. Polish with a leather.

Kitchen Dresser, Tables, and Shelves.—All articles made of wood—pastry and bread boards, &c. &c.—should be washed first with warm water, then scrubbed with sand and a scrubbing-brush. It is best not to wash anything on which food is to be placed with soap, because soap sinks into the wood, and may afterwards flavour the food. If tables are very greasy and dirty, a little soda may be used in washing them, but soda tends to make boards look black instead of white.

Plates, Dishes, etc.—Have ready two large bowls (tin bowls are better than wooden ones for washing dishes, because they do not absorb the grease). Fill one of these with hot water, with plenty of soda in it; the other with plain cold water. Scrape the plates, wash them in the hot water, rinse them in the cold water, and place them in the plate rack, and let them remain till dry. Change both waters frequently.

Gridirons and Frying-pans should be cleansed with scrupulous care. They should be washed with hot soda and water, and dried thoroughly. Gridirons should be rubbed with scouring-paper after being washed.

Cake-tins and Omelet-pans.—Scrape them out thoroughly as soon as done with, and rub them well inside with a cloth or piece of paper till thoroughly clean.

Glass.—Wash in luke-warm water, in which a little soda has been dissolved. Rinse in cold water, dry with a cloth, and polish with a leather. When glass is not in use, it should be kept upside down.

Cups and Saucers.—Wash in hot soda and water, rinse in cold water, and dry with a soft cloth.

Milk-jugs, Feeding-bottles, etc.—Fill vessels which have held milk with boiling water. Let it stand a while, then empty it, and wash well inside and out. Animal

germs found in milk are killed by boiling water, but they grow in warm water. If these germs remain in the vessels, they will be likely to cause diarrhœa in those who drink from them.

Knives.—Wipe dirty knives with a dish-cloth, put them into a jug containing hot soda and water, and be careful that the water does not touch the handles. Shake them about for a minute or two, rinse in clean water, then dry. If there is no knife-cleaner at hand, sprinkle knife-powder on the knife-board, and rub the blades of the knives quickly backwards and forwards till bright. Wash the handles separately with a cloth wrung out of warm water, and wipe them dry. Knives flavoured with onions or any other strong flavour should be stuck into the earth for a while.

Forks and Spoons.—Place these also in a jug containing warm water and soda, wash and wipe dry. Great care should be taken in wiping forks to remove the dust from between the prongs.

A Mincing-machine should be cleaned as soon as done with. If any meat is left in it, this will decompose and spoil the next meat which is put in. A mincing-machine should be taken to pieces entirely when cleaned, wiped out with a damp cloth, and dried thoroughly.

Dish-covers.—Wipe the inside of a dish-cover as soon as done with. Clean the outside twice a week, first with soap and water, afterwards with whiting.

Pudding-cloths, Dish-cloths, etc.—Wash cloths of this kind directly they are done with in hot soda and water, rinse well in cold water, pull out and dry in the open air. Let pudding-cloths hang till wanted in a place where the air can get to them, and rinse in boiling water before using them again.

Coffee Pans and Kettles.—Wash inside and outside with hot soda and water. Polish the outside with bath-brick.

The Kitchen Sink should be scrubbed down every day with soft soap and boiling water, then rinsed with cold water. The edge of the sink should be scoured with hearth-stone, and the tap made bright with polishing-paste and a leather.

Coppers should be dried out thoroughly after being used. They may be kept in good condition for a long time if the flue is swept out with a long sweep's brush each time the copper fire is lighted. Chimney-sweeps are very fond of taking out the copper, thus causing it to be re-set; but this is seldom necessary if the flue is cleared regularly from soot by means of a sweep's brush. The small hearth which opens into the copper fire should be washed and whitened every day. Many servants sweep the daily dust of the kitchen into this hole, and carry it away once or twice a week, but this is a dirty practice.

Cisterns should be cleaned out every three months at least. Plumbers are usually employed to do work of this kind, and they should be well looked after, otherwise they will clean the bottom of the cistern but not the sides.

Cleaning Boots and Shoes.—The dirt should be thoroughly brushed off boots and shoes before any blacking is laid on them. When the dirt and the previous layer of blacking is removed, the blacking may be laid on very thinly, and polished. Sometimes careless cleaners do not thus brush the dirt away, but lay the blacking upon it, and polish over it. No more certain method can be adopted of spoiling good boots.

The floor of a scullery should be washed every day; twice a week it should be scoured. If the kitchen floor be covered with matting or carpet, this should be taken up and shaken twice a week, the floor underneath being well washed. When kitchen floors are made of boards, and are without covering, these should be scrubbed with sand, and rinsed well twice a week, in accordance with the instructions given for washing bed-room floors. No part of a house gets so easily into bad condition as a kitchen floor. In this particular a little neglect causes a great deal of trouble afterwards. If kitchen floors are to be kept white, it should be remembered that plenty of clean water must be used in washing them, and that they must be well *rinsed* as well as scrubbed. Kitchen floors marked with grease may be cleaned with fuller's earth and sand. Stone floors are frequently washed over with a flannel dipped in milk to make them look black.

Kitchen Cupboards should be tidied every day and cleaned every week, the shelves being washed down and covered with clean paper, and the walls swept to remove cobwebs and dust. All jars should have labels pasted on the front, upon which labels the names of the contents of the jars should be clearly written. These jars should be provided with lids to keep out the dust. Every three months they should be emptied, scalded, wiped dry, and re-filled. On the inside of the cupboard door should be pasted a list of everything which the cupboard contains.

Kitchen Chimneys should be swept frequently. An invariable rule cannot be laid down, because so much depends upon the construction of the chimney. The fact that the chimney has been swept should be made the occasion for washing the paint and sweeping the walls in the kitchen.

When the daily work is over, kitchen windows should be opened to ventilate the place and dispel unpleasant smells. The windows in a kitchen should be cleaned every week.

Washing Linen.—It is, perhaps, desirable that a word or two should be said here about the methods to be adopted in washing linen, a very important department of cleaning. To *get up* linen is ornamental, to *wash* it frequently and thoroughly is indispensable for cleanliness. In modern houses it is becoming more and more usual to send linen out to be washed, and the practice is objectionable, first, because too little care is taken as to where the clothes go, so that there is a danger of their being sent to houses were infectious disease is present, in consequence of which the mischief spreads without let or hindrance; and secondly, because the majority of laundresses use deleterious compounds in washing, in order to save labour, and thus the fabric is destroyed. It has been found that linen washed carefully at home lasts years longer than that which has been sent out to wash. Some housekeepers wash a portion of the linen at home, and send out the remainder. Where this can be done without inconvenience, it is an advantage.

A good deal of the difficulty connected with washing linen would be overcome if servants could realise the benefit to be derived from soaking dirty linen in cold water for several hours before attempting to wash it. Soaking in cold water does for dirty linen what soaking in cold water does for beef which has to be made into soup or beef-tea; it *draws out*, in the one case what is objectionable, namely, dirt; in the other case what is valuable, namely, the juice of meat. Linen which has been soaked for some hours, then wrung out, is half washed before washing is begun.

Yet servants will not believe this; they think that additional trouble is entailed by the soaking process, and so they begin straight away to soap and rub, or brush, or work in a machine, give themselves more to do, and spoil the colour of the linen as well.

So effectual is lengthened soaking in drawing out dirt, that there are clever housekeepers who pride themselves on their achievements in the laundry who make no attempt whatever at rubbing the linen excepting in the soiled parts. They simply soak the linen for several hours, draw off the dirty water, soap and rub the soiled portions, put the linen into the copper with plenty of cold water, to which three or four large spoonfuls of soap jelly, mixed with warm water, have been added, bring it gently to a boil, let it boil for twenty minutes, then rinse it, and it is ready to be blued and dried. It will be remembered that, according to the method usually adopted, all white things are washed through twice, or "firsted" and "seconded;" "firsted" on the wrong side, and "seconded" on the right. The soap jelly spoken of here is made by shredding soap and boiling it till dissolved in four times its bulk of water, then adding a small quantity of soda which has also been dissolved. Even when the quick method is not adopted, soaking the linen is a most decided means of saving labour. No one who has once tried it would be so foolish as to begin to wash "white things" without going through this preliminary process.

Flannels and Coloured Things should not be soaked. They should be washed quickly in a good lather of luke-warm water, and dried immediately in the open air. No soda should be used for them. Salt put into the water used for washing coloured things will help to preserve the colour. The water in which a few ivy-leaves have been boiled may be used for rinsing black things, a little alum may be added for greens and blues, and soda for violets.

Blankets, Woollen Antimacassars, etc., should never have soap rubbed upon them. Like flannels, they should be washed in a good lather, and hung out to dry at once.

Grease in Linen may be removed by putting plenty of soda in the water in which the linen is washed. When linen is not greasy the use of soda, except in small quantities, is objectionable, as it spoils the colour. A little borax used instead of soda for "small whites" will soften water, and will not do any harm.

Laces and Muslins should be soaked in water in which a pinch of borax has been placed. They should not be rubbed, but should be dabbed and pressed in a good lather made with curd soap. If very dirty they may be put into a basin with cold water and a little shred soap, covered with a plate, and set in the oven for a quarter of an hour, then rinsed. If the écru shade is required, tea or coffee may be put into the rinsing-water.

Black Lace may be washed in water with a little green tea or ammonia.

White Silk Stockings should be washed quickly in a luke-warm lather of curd soap, and dried at once. For *Black Silk Stockings* ammonia may be added.

Crewel-work, Washing-silks, etc. For these tie a quarter of a pound of bran in a muslin bag, and toss this in luke-warm water till there is a lather; wash out quickly, and dry at once in the open air in the shade, or away from the fire.

Scorches may be removed if attended to as soon as made. Apply a little onion-juice (obtained by crushing a boiled onion) and mixing with it a very small

quantity of vinegar, white soap, and fuller's earth. Wash the linen thoroughly after the scorch is taken out.

Iron-mould may be eradicated with salts of lemon. Damp the place well and stretch it over a pewter vessel, and work in a little of the salts, rubbing it round and round till the stain disappears. Rinse thoroughly till every particle of the acid is gone. All stains should be dealt with before the linen is washed. Soap "sets" a good many stains, though it takes out a few.

Beetles or Cockroaches frequently infest kitchen and basement floors, and are exceedingly objectionable. Various methods are adopted to get rid of them, all more or less effectual. Amongst others the following are to be recommended:

Have the holes, chinks, and crannies in the floor and wall through which the beetles make their way, filled up. This alone will do much to put a stop to the nuisance. Place beetle-traps about the kitchen at night. A trap for the purpose may be bought. It consists of a wooden box with sloping ends, and a glass cup which has a hole in the bottom fixed in the centre. A little sugar is sprinkled at the bottom of the trap, and the beetles drop into the cup to obtain it, and are caught. A very successful trap may also be made by putting a little stale beer or a little treacle in the bottom of a basin, and a piece of wood with one end resting on the floor and the other on the edge of the basin, by means of which the beetle can reach the basin. Once in it cannot get out again. Or a piece of wood smeared with treacle may be floated in a broad basin of water. In trying to reach the sweet the beetle will be drowned. Various poisons in the shape of wafers, pastes, and powder are sold for killing beetles, or borax is spread in the places which they infest. If all these means should fail, a hedgehog should be procured. It is almost certain to frighten the beetles away.

Once a year the ceilings and walls of a kitchen should be cleansed. If the walls are painted or papered and varnished, they will have to be washed with cold water, soap, and flannel. The ceiling also must then be newly whitewashed. If walls are coloured in distemper, the colouring must be removed. Distemper colouring is, however, the most objectionable covering for kitchen walls that can possibly be employed. It is cheap to begin with, and, on this account, it is very commonly adopted; but it is dear in the long run, because it requires to be renewed so frequently. The size with which it is mixed, and which is often of the commonest description, renders it impure and unwholesome. Sometimes distemper is varnished, and when this is done, it is not so objectionable.

The best coating for kitchen walls is oil-paint. It is more expensive in the first instance, though really the amount of the expense is determined more by the ideas of the painter than by the cost of his work. When once done, however, it lasts for years, and can be washed, and thus rendered fresh and sweet, at any time.

Larders, Outhouses, etc.—Whatever may be the opinion as to the advisability of using distemper-colouring for kitchen walls, there is no question about its unsuitability for the walls of larders, wine-cellars, &c. These (where not tiled) should be lime-washed, and the lime-washing should be renewed at least once a year. Lime-washing is, at any rate, pure and wholesome. It is frequently objected to because it rubs and drops off after a while. Unfortunately, it is not easy to mix lime so that it shall not rub off a little. The plan usually adopted is to slake quick-lime in water. If the wash were used in this condition, it would be sure to rub off,

for there would be nothing to fix it. Size, the fixing-material employed in mixing whitewash and distemper colours, is no good here, because the corrosive action of the lime destroys the glue. Boiled linseed-oil, tallow, or alum, are sometimes used separately, but none can be said to be thoroughly effective, although the first-named is perhaps the best. When it is used, water should be poured upon freshly-burned lime to make a wash of the consistency of thick cream, and boiled linseed-oil should afterwards be added in the proportion of a pint of oil to a pailful of limewash. In this case a brush made of vegetable fibres should be used, because the lime would destroy a brush made of animal bristles.

If the size were not objectionable, there would be no difficulty in mixing ordinary whiting with size to make a wash that would be sure not to rub off. But size is made by boiling the bones and skins of animals to extract the gelatine, and as we should never think of keeping a bag of old bones, or the skins of animals, in a larder with our food, so we ought not to put these things in another form on the walls of our larder.

The larder is a part of the house which is frequently neglected, and yet it ought to be looked after and cleaned with most scrupulous care. The window should be left open whenever the weather will permit of its being so, in order that there may be a good draught of fresh air constantly passing through the place. The shelves should be tidied every day, and all food which is not in good condition should be at once removed, because decay in one thing will be communicated to others. Mouldy cheese, rancid butter, sour milk, and tainted meat should never be kept in close proximity to other food, neither should strongly-flavoured ingredients, such as bloaters or onions, be put on the same plate with butter or bread. Dirty plates and dirty dishes should be taken out as soon as they are done with; more than all, jugs and bowls which have contained milk or cream should be carried away as soon as they are empty. Once a week, and, if possible, twice a week, the shelves of the larder should be scrubbed with sand and warm water, and the floor should be scoured. The windows also should be kept clean and bright. Where the walls are lined with tiles these should be washed occasionally with carbolic acid and cold water.

Bread-pans should be wiped out with a damp cloth and dried every day, all crumbs and stale pieces being emptied out. Once a week the pan should be scalded and put into the open air for a while. The lid should be washed as well as the pan, and the latter should never be left uncovered.

A good deal may be done in the way of keeping meat sweet by taking steps to preserve food in good condition. Thus, meat should never be laid on a plate, but should be hung in a draught from meat-hooks fastened into the ceiling; it should be examined every day, and wiped with a clean cloth. Milk should be boiled before it has time to turn sour, and cheese should be closely covered. In hot weather butter may be preserved by laying it in cold water set in another vessel also containing cold water, in which a little saltpetre has been dissolved. A linen cloth, the ends of which are laid in the saltpetre water, should be spread over the butter. Green vegetables also, and potatoes, should never be laid on the shelf of a larder; they should be put upon a dry stone floor, where frost cannot get to them. There would be no difficulty in keeping larders clean if mistresses would form a habit of going to the larder every morning in order to satisfy themselves that it is properly

kept. Meat-hooks should be wiped clean each time they are used. In hot weather a basket containing pieces of charcoal, to be renewed every week, may be kept in the larder.

Coal-cellars and Outhouses should be lime-washed once or twice a year. Unless this is done spiders and other insects will make their home in them, and will wander thence into the other parts of the house. When the supply of coal is finished, and before fresh coal is got in, the opportunity should be taken to clear a coal-cellar, and to sweep the walls if they cannot be lime-washed. Care should be taken also to use the dust belonging to one stock of coal before another supply is ordered. It may easily be burnt to profit in the kitchen if moistened with cold water and mixed with cinders, and if allowed to accumulate it will be blown all over the house in windy weather.

Dust-bins.—Nothing that is wet or even damp should be thrown into a dust-bin. If it is, it will become mouldy, and will cause a musty and very objectionable smell. Dust-bins should be emptied frequently.

According to the orthodox method of cleaning a house, the cleaners should commence at the top of the house, and work steadily down till they get to the bottom, carrying dirt before them as they go, and doing the kitchens last. The theory is an excellent one, and, no doubt, is correct when applied to empty houses, or to houses given up to cleaning by the family. Experience teaches us, however, that where houses have to be cleaned while the family remain at home, and ordinary house-work has to be carried on simultaneously with the cleaning, it is best to do the kitchens and pantries first, and then go up to the attics, and come downstairs, doing the sitting-rooms after all the bed-rooms are finished, and the stairs and passages last of all. The reason for this is that the highest attic cannot be cleaned except through communication with the kitchen, and, if the latter is dirty, the dirt will be trodden backwards and forwards, and a perfect condition of cleanliness will not be attained. Besides this, the cleaning of the kitchen and pantries is usually the heaviest and most disagreeable part of the cleaning, and, therefore, it should be done while the workers are fresh to the business, and feeling energetic and cheerful about it, not when they are tired out and dispirited.

Again, when a house has to be cleaned while the family are at home, it is not advisable that it should be gone on with day after day without cessation until all is done. It is best to arrange and divide the work and take rest between, otherwise it becomes unbearable. If the business is begun early in the year, and one or two rooms are done each week, and then the cleaning is left for a few days, it may be managed so that the worst of the cleaning is got through without the family being inconvenienced. It is no use cleaning rooms where fires have been until the fires are done with, and it is impossible to keep the fact of cleaning a secret when the sitting-rooms in daily use are being turned out; but the matter should be kept quiet as long as possible, and the unpleasantness arising from it made as short as may be. If periodical cleanings were planned beforehand with this object in view, they would not be objected to so strenuously as they now are.

Clever housekeepers say that no house is thoroughly clean until it "has been cleaned up after the clean." This is quite true, for even to clean makes dirt. Also it is true that the fact that a house has been thoroughly cleaned is no reason why efforts directed towards the maintenance of a condition of cleanliness should

be relaxed in the slightest degree. Constant daily doing will do more to keep a house clean than any amount of energy which finds vent in occasional spurts, alternated with seasons of indolence and indifference.

There are people in the world who think that spring cleanings can be dispensed with, and that if a house be kept clean constantly, it need not be cleaned periodically. Persons of experience, however, do not speak like this. Houses may be kept as clean as it is possible to make them, and yet special work will have to be done which can only be undertaken at certain intervals and under unusual conditions. Spring is the time chosen for whitewashing, painting, papering, and cleaning, because days are longer and brighter, fires are done with, and the dirt caused by fires, rain, mud, and fog has to be removed. Autumn also is chosen, because at that season the house has to put on its winter attire and prepare for darker days.

When we have once realised the fact that dirt is the parent of disease, and the enemy of health, purity, energy, and refinement, we shall not hesitate to take trouble to lay down plans and adopt methods for its removal. A great philosopher once said that "dirt was only matter in the wrong place." It does not concern housekeepers to discover where its right place may be; they may content themselves with acting upon the conviction that it is in the wrong place when it is in their houses.

SICKNESS IN THE HOUSE.

BY THE EDITOR.

CHAPTER LXXXVIII.

GENERAL ARRANGEMENTS.

Situation of Room—Size, Ventilation, Lighting, Furniture—The Nurse.

THE authors of the preceding parts of our book have told us how to build, arrange, and fit our house, so that its inhabitants may be best free from the greatest curse to humanity—ill health. They have told us how we may avoid the injurious effects of damp and cold, how we may best maintain the temperature of the rooms in which we dwell without experiencing the discomforts arising from excessive heat or want of ventilation, how our drains should be constructed to prevent the entrance of baneful emanations into our rooms, and how we may supply ourselves with pure water. We have been taught how to light the house in the best way, how to decorate it, and how to keep it clean. Living under these conditions we may well hope to be free from many diseases, and certainly from all those which directly result from an ill-constructed habitation. But, unfortunately for the human race, it is heir to many ills bequeathed by our forefathers, whose knowledge of what to avoid on the one hand, and whose power of applying this knowledge on the other, was far more limited than our own.

We must not, therefore, expect that, because our house is dry, we shall never suffer from rheumatism or catarrh; that, because our rooms are well ventilated, headaches will never be known to us; nor indeed have we any right to anticipate that enteric fever, the disease of all diseases which belongs to faulty drains, will never enter our doors. Enteric fever, scarlet fever, diphtheria—in fact, all the long list of infectious diseases, may be contracted outside our house, and thus disease creeps into the most healthy home which all our knowledge can enable us to build. Nor are infectious illnesses the only class of disease with which we may have to deal in connection with our healthy home; persons suffering from a host of chronic ailments, from lung, from kidney, and from heart disease may come to inhabit it.

Many diseases come to us as the result of advancing years. The changes which we find taking place in the hair are equally present in all parts of the body; the lungs are altered, the heart and blood-vessels, in their ramifications through the whole body, degenerate, the bones become brittle, and health, as the result of these changes, is liable to many interruptions. There are diseases due to faults of living, to exposure, and to carelessness, besides those which come about as an inheritance of our forefathers; all of which, it is left to the writer to point out, may have to be provided for in the house, concerning which his colleagues have laid down rules to prevent having in it any sickness at all.

For all persons suffering from these diseases we must insist upon the same advantages as have been pleaded for those in a state of health; that is to say, the rooms they occupy must be sufficiently ventilated, sufficiently warmed, and sufficiently lighted to suit the requirements of the sick person; but he has other necessities than these. The pleasure which he derives from his association with others in a time of health will cease to be a pleasure in a time of sickness, that which has before afforded him amusement will then prove irksome and injurious; he must have the opportunity of passing his time in the manner best suited to his physical and mental condition, and the first demand which, therefore, has to be met, is to provide for him the rest and quiet which his ailment requires. The room to be chosen for the use of the invalid, if the illness be a severe one, must be as far removed from bustle and noise in the house as circumstances will permit, provided that the duties of tending upon him and supplying him with food shall not be impeded by removing him too far from those upon whom he has to depend. It is impossible, without regard to such arrangements of the house as the distance from the kitchen, or as the distance from the necessary lavatory, to decide upon the particular room that he shall occupy; but almost every house allows a choice to be made which shall meet the necessities of the invalid and the convenience of the household.

So far as the invalid's own comfort is concerned, it is important, besides his need for rest, to take into consideration the question whether his illness confines him to his bed, or whether some portion of the day will be spent about the room. If he is so ill as to be unable to enjoy the prospect from the window, it is immaterial what the outlook of the room may be; but if this is not the case, or if a period of convalescence will have to be passed in the same apartment, it is desirable that this should not be forgotten, for nothing is more wearisome than to have no better view than that which is afforded by the back windows of some town houses.

The size of the room will affect not only the comfort of the invalid, but the convenience of those who are attending upon him, and it should, therefore, be sufficiently large to allow free movement about it, and ready access to all sides of the bed.

But there are other reasons than these for giving abundant space to any one confined to bed. The room may possibly have to serve for day as well as for night, and thus there is not the same opportunity for so complete a change of its air-contents as every bed-room has when its occupant leaves it in the morning. In the section on ventilation we have been told of the necessity for the change of the air of every occupied room, on account of the accumulation of impure air which would otherwise occur, and that the air of a room can only be completely changed some three or four times an hour without producing draught. In the sick-room, the pollution of the air takes place more rapidly, and the necessity for its frequent renewal is, therefore, increased; but draughts must also be avoided, and one of the means by which this can be done is to have a room containing so many cubic feet of air that the pollution of this larger volume by the sufferer is rendered more difficult. In a larger room, moreover, it is possible to place the bed in a position more removed from the currents which in every room circulate between the door, the window, and the fireplace.

It will be worth our while to learn very briefly the amount of cubic space which

is required for the purposes of the sick by those who have considered the subject. The whole tendency of the thought of those who have charge of the sick in modern times has been to insist on a much larger amount of cubic space than some years ago was considered necessary. A visit to some of our older hospitals will show how comparatively small an amount was claimed a hundred years ago; but in recent years we have come to understand how very much the sick person is dependent upon an abundant supply of fresh air for his chances of recovery, and we are now not satisfied unless in a hospital every patient is allotted upwards of 1,500 cubic feet of air-space, and in hospitals for infectious diseases not less than 2,000. But where a single room comes to be occupied by an invalid, we shall find that even 2,000 cubic feet is insufficient for our purpose, and that we must look upon 3,000 as the smallest amount necessary. If it be recollected that this amount of space is all that can be obtained from a room 12 feet in height and about 16 feet square, it will be seen at once that this limit is by no means an extravagant one.

The temperature of a sick-room must depend upon the particular ailment which has to be treated in it. It is unnecessary to maintain a temperature of more than about 50° Fahr. for a healthy person in bed; in cases of the acute infectious fevers a comparatively low temperature is well borne, unless some lung-complication supervene; but in other diseases, such as bronchitis, asthma, or pneumonia, a higher temperature is often required, and from time to time it may be necessary to render the air of the apartment moist by the introduction into it of steam. But whatever need there may be for warmth, this must be provided for rather by an increase of the fire than at the expense of the ventilation.

A description of the various grates which may be best used with this object will be found in the section on Ventilation and Warming, and we have only to point out, as a special requirement of our siek-room, the very considerable assistance which would be afforded by a small boiler in connection with the grate. With regard to the moisture of the atmosphere, this is most easily produced by the use of a kettle with a long spout; the water in the kettle being readily maintained at boiling-point either by the fire, by a gas-burner, or spirit-lamp.

An abundance of light is one of the essentials of the sick-room—first, to enable every office to be performed about the sick person, and the room to be kept absolutely clean by exhibiting the least deposit of dust; and, secondly, to enable the sick person to derive from sunlight those health-giving properties which it undoubtedly contains, for without sunlight the powers of life, whether of animals or vegetables, become enfeebled, and at no time is there more need for life to be supported than when the bodily powers are weakened by disease. Excess of light can be readily prevented by the use of blinds, and there should not, therefore, be any fear that the window-space will be too great, so long as the size of the window does not hinder the maintenance of a proper temperature in the sick-room. The position of the bed with regard to the window is an important one. We have already said that the patient must not be exposed to the currents of air which circulate between the fireplace and the door, neither should the bed face the window, but should have it on one side, so that the invalid may readily turn from it should he so desire, or may, if he wish to read, have the light thrown upon his book in such a direction as not to cast a shadow. With regard to artificial light, it may be said that whatever rules are laid down by Mr. Brudenell Carter in the

section on Lighting apply with double force to the sick-room, for here especially is there no need for a brilliant illumination of every object in the room; it is enough if there be ample light for the attendants on the sick to perform their duties, while a particular object, such as a book, is readily illuminated by a shaded lamp, which, while casting a light on the book, protects the reader's eyes from the glare.

In the treatment of the floor-surface, different opinions have been held with regard to the question of staining, waxing, or washing it, and one high authority has described any other method of cleaning the floor than that of scrubbing as "rubbing in the dirt;" but latterly opinion has grown in favour of the dry methods, which, it is argued, not only cleanse the surface, but prevent such risks as may arise from making the floor damp. The floor of the sick-room must not be wholly covered with carpet; a few strips placed round the bed and in other parts where specially required, which can be at once removed for the purpose of cleaning, will be sufficient. It is particularly in the sick-room that advantage will be derived from the floor consisting of close-fitting boards.

For walls there is no better covering than that of distemper. The readiness with which the surface can be renewed renders this method infinitely preferable to paper, which necessarily, in course of time, absorbs some of the emanations which are given off from the body. With regard to colour, we have only to urge that this may be sufficiently eheerful without being too pronounced, and that there may be a complete absenee of any pattern which shall trouble the weary brain at a time when there is a tendency to count or shape any form or spots upon the wall.

In arranging the furniture of the room, we must bear in mind the requirements of the invalid and the necessity for maintaining his apartment in as perfect a state of cleanliness as possible. There must be a bed, a chair or two, a table, appliances for washing, and either a night-commode or a bed-pan, or both, as well as convenience for storing a limited amount of clean linen. Beyond his own neeessities and those of his nurse, the less furniture he has about him the better.

A few words may be given to the character of the furniture which is best fitted for use in the sick-room. Beginning with the bed, it may be pointed out that the height above the floor is a matter of importance, for if this be excessive, it is almost impossible for those in attendance upon the invalid to reach over the bed, and raise or move him from one position to another. For the same reason, it is desirable not to have too wide a bed; if it is possible to remove a sick person from one side of a very wide bed to the other, it is equally possible to transfer him from one narrow bed to another placed immediately by the side, a course which is infinitely to be preferred, inasmueh as it enables the invalid to be placed in a newly-made bed without undergoing the fatigue of waiting until his own bed is made, and one, moreover, far more free from emanations given off by the body than that just quitted, however well it might be aired and made.

As a general rule, a mattress placed upon a spring bed is preferable to a feather bed, and where, in surgical cases, it is important that the bed should not be allowed to become uneven, the mattress becomes a necessity. A light iron bedstead on castors is best, for the reason that it can be easily kept clean, and can be readily moved from one part of the room to another; it should not have a high head-board.

inasmuch as this interferes with the easy lifting of the patient by any one standing at the head. Curtains are unnecessary, and indeed prejudicial: unnecessary, because the only plea for their existence is that they prevent draught, and if the bed be placed in its right position in a properly-constructed room no draught should be perceptible; and prejudicial, because they tend to confine the air about the sick person at a time when it is most desirable he should be provided with a plentiful supply.

The necessities of sickness usually require the provision of a night-stool or commode; this should be so constructed as to render it impossible for emanations to rise from the pan, which should, therefore, have a cover, and should immediately after use be removed from the room.

The rest of the furniture relates rather to the comfort of the invalid than to his health, but reference may be made to those tables which extend across the bed, and add so much to convenience in taking meals in bed; some of these tables can be sloped so as to form a reading or writing desk, a great boon during a long illness. A bed-rest is another article of furniture which may be almost considered a necessity, giving opportunity for the invalid to sit up at any angle without undue fatigue. Many other appliances are now made to suit the requirements of individual illnesses, but it would be out of place to describe them here. It should, however, be remembered that whether the invalid be in bed, or be sitting up out of bed, the furniture should be so arranged as to enable him to adopt with the least fatigue the position which is best for him, and which helps him to enjoy all the change of posture he may require.

But, however much the invalid may be dependent on the furniture and fittings of his room, not only for his comfort but as aids to his recovery, he is far more dependent upon the personal services of those whose duty it is to tend him during his illness. Upon the influence of the nurse for good or for evil his chances of life will often altogether depend. It is not every woman who can make a nurse, although we are not infrequently told that women are born nurses; nor, indeed, does every woman who earns her living by nursing deserve to have conferred upon her this honoured title.

Miss Catherine J. Wood, the able Lady Superintendent to the Children's Hospital in Great Ormond Street, writing on nursing, says that six general qualifications are needed to make a thorough nurse—viz., presence of mind, gentleness, accuracy, memory, observation, and forethought. "Nurses should be conscientious attendants on the sick, handmaidens to the medical staff, a happy mean between the drudge that does all the dirty work and the quasi-woman doctor of modern times—the bane of the sisterhood and the plague of the doctors."

A nurse should be a woman in good health, of cheerful disposition, and exercising a proper control over her patient, yet not in a way so authoritative that he shall be conscious of his helplessness. A knowledge of the responsibility attaching to her office should lead to her devoting her best energies to her duties, while a further knowledge that she is equal to any claim that may be made upon her should free her from an undue sense of anxiety, which might impart to her patient a sense of insecurity.

Before all things she should be noiseless in her movements, and to enable her to

be so, her dress should be arranged with this object, for nothing is more trying to the sensitive and feverish patient than the creaking of boots and the rustle which accompanies every movement of the highly-starched nurse. She should be methodical in her habits, and careful to keep the sick-room as tidy as possible, for to a nervous patient the fact that the room presents a disorderly appearance is often most distressing.

Nor must it be forgotten that the nurse herself must be considered in the arrangements which are made for tending on the sick. She must have her proper hours for sleeping and for exercise, for the former not less than eight, for the latter fully two hours. She should not be expected to take her meals in the sick-room, but in all details her health must be studied, not only as necessary to the proper performance of her duties, but also in fairness to herself.

CHAPTER LXXXIX.

ARRANGEMENTS FOR INFECTIOUS DISEASE.

Advantages of the Removal of the Sick—Choice of Sick-room—Preparation of Room—Special Precautions for Different Diseases.

As yet we have only pointed out the arrangements which must be made in view of the welfare of the sick person alone, his illness being no concern to the other inmates of the house, except so far as they may entail anxiety and labour upon them; but it is hardly possible for a house to be inhabited by a mixed population of persons of all ages for many years, without the introduction into it of some form of communicable disease.

To every householder, to the head of every family, the question must at some time present itself, what is to be done to prevent the disease, from which one person is suffering, extending to others? The very great probability that provision will have to be made for such an eventuality will be best understood by pointing out that the Registrar General's returns for the year 1881 show that as many as 6,723 children during the first five years of life died in London from small pox, measles, scarlet fever, diphtheria, whooping-cough, typhus and enteric fever. These deaths may be taken generally to represent at the very least ten times the number of cases of sickness, and occurred among a population of about 450,000 children under five years of age. Now, if we reckon the number of cases of these diseases at this age to be 70,000 in London during 1881, we may roughly calculate that 350,000 such cases occurred in the five years; or, in other words, that 35 out of every 45 children under five years of age suffered from one of the above-mentioned infectious diseases before it had attained that age.

Such, then, must be the expectation of every household with young children, while those dwellings which are inhabited by older people must also from time to time contain persons suffering from infectious disease. This being the case, it is well for every one to know how he can best limit the further extension of the disease which has invaded his home. Immediately the fact is known that one of the family is suffering from scarlet fever, from diphtheria, or from any other of these diseases, a hundred questions are at once asked. Are the children to remain at home? What is the risk to them if they do? Where shall the sufferer be put? How shall the room be prepared? What disinfectants must be used? Upon the correct answers to be given to these questions will depend the health and, perhaps, the life of more than one inmate. They ought, then, to be carefully considered before the emergency arises, and every house ought to be so ordered that no time shall be lost in making arrangements upon which so much depends.

We are often told that a "little knowledge is a dangerous thing;" and the proverb is true enough, frequently leading us to trust to that knowledge when we should be acting more wisely were we to seek advice from some source where we could obtain guidance upon which we might rely with safety. We do not propose, therefore, to suggest such rules for the guidance of families that the medical attendant should

be in any way considered unnecessary; but we would rather wish to explain the reasons which are the cause of the orders given by the doctor, and thus enable those whose duty it is to carry them out, to understand how best to give effect to them.

Now, the diseases which are communicable from man to man can be conveyed in several ways—by contact, by means of air, by means of some person in close relation to the sufferer who is not himself attacked, by some infected article, such as clothing, or by some infected food-supply, such as milk or water. Hence, if the infectious person is not to cause risk to other people, he must be placed under conditions which make it impossible for him to infect the air breathed by others, the food swallowed by others, or any article of clothing or furniture, or indeed anything that can while thus charged with infection come itself in contact with a susceptible person. We must, indeed, "isolate" the invalid, and by the word isolation we mean that he is to be so cut off from all others likely to contract his disease, that they will not be exposed to any of the risks we have indicated.

It is clear that the first thought which will enter the mind of the head of a family, one of whom has contracted an infectious disease, is, whether the disease can be treated without risk in the house, and, if it cannot, what course shall be adopted? Shall the invalid be removed, or shall he remain while other members of the family, who are themselves susceptible to the disease, are sent away? Whatever the conclusion may be, it must be arrived at promptly, for every moment of delay increases the probability of the disease spreading to others.

If there be a hospital within reach of the sufferer to which he can be removed, the whole difficulty is at an end; and here it may be fitting to point out how very much needed is hospital accommodation for those who are willing and able to pay for the same comforts with which they would be surrounded were they to remain in their own homes. In London this accommodation exists, for the London Fever Hospital in Liverpool Road, Islington, has wisely provided a series of separate rooms in which for a small weekly payment every necessary and every comfort can be had by persons suffering from infectious fevers; while the London Small Pox Hospital at Highgate has also made provision for cases of small pox.

That this is the simplest and wisest course in the great majority of cases is evident; and it may be stated that this removal of the invalid may, as a rule, be effected without the least risk in the ambulances provided either by these institutions or by the sanitary authorities of the district in which the infected house is situated. This is a point worth dwelling on; for the fear of causing injury to a person stricken with infectious disease is often so present in the minds of his friends that he is retained at home, to the great risk of those who are dwelling in the house with him. Indeed, the writer feels he may speak with some assurance on this point; for of some thousands of cases of all kinds of infectious disease which have come under his observation, he has known but a very few persons whose condition was rendered the worse for their journey, and these were, without exception, persons whose illness had far progressed before the removal took place; while of those who were removed within a short time of the beginning of their illness, not one suffered from the journey or the change of abode, although this took place at all periods of the year.

When the removal either of the sick person, or of other members of the family, is a necessity, the advantage of the former step must be insisted upon, particularly because

if the other members are distributed to different houses, this may occur at a time they are themselves incubating or hatching the disease, and thus they may, in their turn, become centres of infection to other families; while, on the other hand, if they can be retained at home without further risk to themselves, they are necessarily under close inspection, and the area of disease, should subsequent cases occur, is thus limited.

If, however, neither the sick person nor other susceptible members of the family can be removed from the home, it becomes necessary to isolate the former in the best manner possible, and we must now consider how this can be done.

The separation of the sick person is to provide against infection being carried by air, in the first instance, and for this purpose it is necessary to place him in that part of the house of which the air can be most readily cut off from that of the rest. In most houses of the middle class in London or other towns, the best situation will be at the top, where he should have one or more rooms to which he should be absolutely confined. In many of these houses there are not more than two or three rooms on the floor, and none of these should at this time be allowed to be occupied by any but those who are in attendance upon the sick person. As a means of further cutting off the air communication between the sick-room and the staircase, the Society of Medical Officers of Health have recommended that a sheet should be hung over the doorway, and kept saturated with a solution of carbolic acid. We will shortly discuss the merits of the different disinfectants; at the present moment, therefore, we will be satisfied with the statement that a sheet thus hung before the door serves as an additional barrier to the passage of air, and it may be taken as a fact that this method does undoubtedly offer an obstacle to a current of air entering the window and driving out the infected air of the room on to the staircase.

This is the best position for an infectious person in the ordinary middle-class house, where there are three or four floors of two or three rooms each. In houses differently arranged, other rooms might serve the purpose as well or better.

The accompanying plan (Fig. 410) shows an arrangement of rooms where two bed-rooms, a water-closet, and a bath-room are grouped together, and can be entirely cut off by a properly-arranged sheet or curtain at A from the rest of the house. This arrangement has stood the test of a practical experiment; for in the rooms to which we have referred were isolated a child suffering from scarlet fever, and her nurse, while living in the rest of the house were five adults and four other children, but one of whom had previously had scarlet fever; yet they remained in the house during the whole time of the illness and did not contract the disease.

Our next duty is to consider the changes necessary to prepare the room for the reception of a case of infectious disease.

To speak generally, the room should be denuded of everything not absolutely required for the use of the patient and his nurse. All curtains should be removed, the carpet should be taken up, a strip only being left which can subsequently be destroyed. The chest of drawers should be emptied of everything except that which will be required during the illness, or during convalescence. Superfluous furniture should be removed, so that as little opportunity as possible should be given for infectious particles to deposit themselves in the nooks and corners of unnecessary articles.

With the room in this condition the sick person passes through his illness,

except that the remainder of the bed-room furniture which is required during a state of health has to be somewhat supplemented during sickness, but these details have been already considered.

Thought should now be given to the passage and staircase; they should be kept as freely ventilated as possible; the staircase window should be kept open, all doors opening on to it carefully shut, and the stair-carpet removed.

With such arrangements thoroughly carried out, there is every probability that the other residents in the house will only be exposed to one risk—that of infection carried by the person in attendance upon the invalid.

In selecting the individuals who are to undertake this duty, regard must be had to the fact that they are themselves exposed to infection, and they must, there-

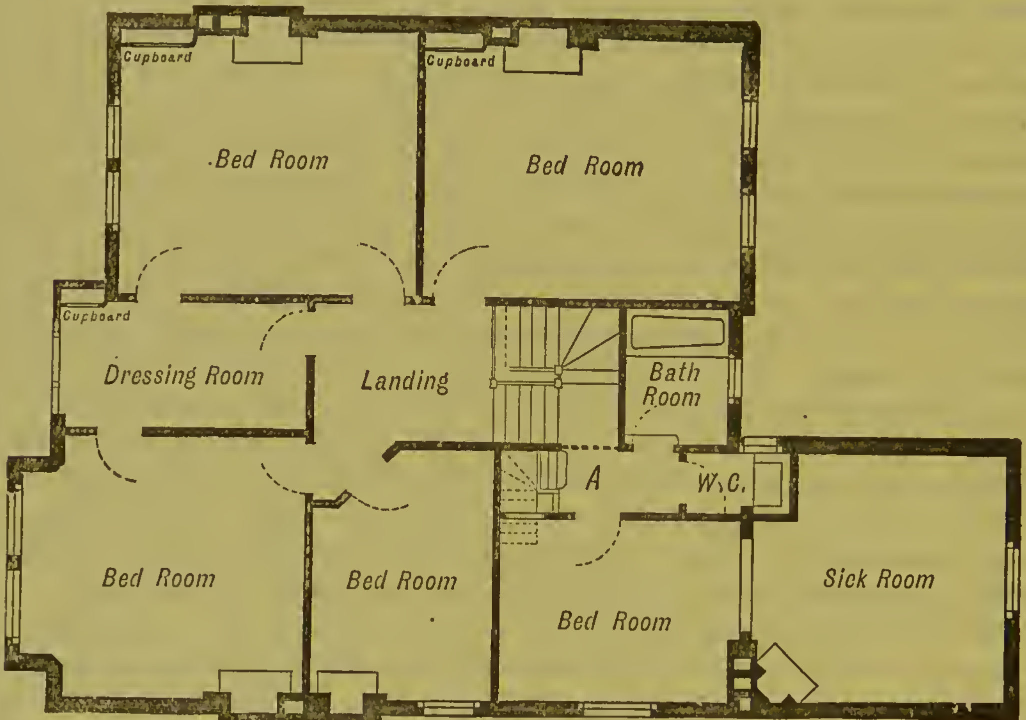

Fig. 410.—Arrangement for Infectious Diseases.

fore, be chosen not only for their capacity to take good care of their patient, but they should, if possible, have passed previously through an attack of the same illness as that from which he is suffering. This is an important point, and should on no account be lost sight of; for, apart from the consideration which is due to her, if the nurse fails through sickness, she adds to the difficulties of the household not only by the loss they sustain of her services, but also by the fact that she in her turn needs the help of others.

For the purpose of doing her duty to her patient, and to the other members of the family, she must have an appreciation of the dangers against which she has to guard, and must understand intelligently the means which are to be adopted with this end. She must recollect that upon her devolves the whole responsibility of carrying out the doctor's orders in such a way that by no oversight can infection pass from the sick-room into the rest of the house, and it cannot be too strongly pointed out, that unless the greatest possible care be unceasingly taken to prevent

accidents, the strict quarantine will be broken, and misfortune will be likely to follow.

The nurse should have opportunity given her of wearing clothes while on duty in the sick-room different from those which she would wear at other times. It is obvious that her clothing must, from contact with her patient, become itself charged with infection, and she should, therefore, limit this exposure to one set only, never taking her other clothes into the sick-room. Her movements in the house will depend upon whether children or other people susceptible to infection are living in it. She should, however, not go into other rooms without first changing her clothes and washing herself thoroughly; and it is necessary that even with these precautions she should be kept away from susceptible people. It would not be fair to expect her to take her meals in the sick-room; these may be brought to her in one of the rooms which are to be avoided by the rest of the household. Living thus separated from the world, she should not be forgotten, and everything should be done to enable her to preserve her own health.

Finally, her age comes to be a matter of importance when she is called upon to treat one disease from which she has not previously suffered—viz., typhus fever. It is desirable that if a woman must be employed to nurse typhus, who has not passed through an attack of this disease, that she should be as young as is consistent with the possession of sufficient knowledge and experience to take charge of her patient. The greater the nurse's age, the less her chance of recovery should she be unfortunate enough to contract her patient's disease; and it is a most improper and unfair act to expose a woman of middle life, or of riper age than this, to the infection of typhus, unless she has previously had the disease, or unless no younger person can be found suitable for the work which has to be done. On the other hand, it is believed that young persons are far *more* susceptible to attacks from enteric fever than those who are older; this point also should be borne in mind in the selection of a nurse.

With regard to the patient, everything he uses should be kept distinct from articles used by other persons; his linen must not be allowed to mix with others in the general laundry, but should be specially treated, while rags which may have been used to receive the discharge from the throat in scarlet fever or diphtheria should be at once burnt.

We have now discussed the arrangements that should be made in a household for the treatment in it of a case of infectious disease; and it only remains to consider how far they are necessary for all the infectious diseases, and whether any relaxation of these rules may be permitted with regard to any one disease, or whether they must be supplemented by others.

The answer to questions such as these must, of course, depend upon the manner in which the disease is communicated from the sick to the healthy. Thus, some diseases are caused by infection carried by air directly from the patient, while in others the poison appears to exist more particularly, if not altogether, in the discharges from the patient. In the former class, atmospheric disconnection is absolutely necessary, while in the latter it becomes more important to take precautions with regard to the discharges.

The diseases which are especially communicated by infected air, or by infected clothing, are measles, small pox, chicken-pox, scarlet fever, and diphtheria. For

these the strictest quarantine must be observed if the infection is to be limited to the room occupied by the sufferer; but with regard to small pox we have another means of protection which is far more to be relied upon than any of the methods to which we have referred. If a case of small pox occur in a dwelling, and the other members of the house be properly vaccinated and re-vaccinated, so far as they are concerned there need not be the least apprehension that the disease will extend. If they be not already protected in this way, they can secure themselves against the disease by being *immediately* vaccinated. If this be done within forty-eight hours of the first exposure, they will escape the disease; but if another twenty-four hours elapse the disease will only be modified, while if this time be exceeded the invalid will pass through his small pox in the same manner as if he had not been vaccinated at all. It will be well here to point out that vaccination should, especially under these circumstances, be done directly from an infant's arm or from a calf; the lymph preserved in tubes or on ivory points has a tendency to deteriorate, and ought not to be trusted to unless *direct* vaccination is impossible. Indeed, the very fact that small pox should at any time occur presupposes an amount of negligence, seeing the readiness with which any person may make himself proof against this disease. The object, then, of isolating in a house a person suffering from small pox should be rather to prevent the infection of susceptible people who may visit the house during or after the illness, and over whom the family have no control, than any member of the family itself, seeing how readily they can be protected by vaccination.

In cases of scarlet fever, it has been recommended that the skin should be anointed with oil to prevent small particles, which are so freely given off before the end of this disease, from being carried by the air to susceptible persons. If this course should be adopted, it must not be allowed to interfere with the most thorough cleanliness of the patient, nor must it be trusted to the exclusion of other precautions, seeing that there is no evidence that the skin alone gives off infection.

The fact that scarlet fever and diphtheria have been found to be disseminated by a contaminated milk-supply is a reason for pointing out that no possible opportunity should be given for the infection of this article of food, although it is only by great carelessness that such an occurrence is possible.

Enteric or typhoid fever, or gastric fever, as it has lately become the fashion to call this disease, is one in which the poison is known as an absolute fact to reside chiefly in the bowel-discharges, and there is an absence of evidence that the disease is communicated in any other way than through them. In this disease, then, there is perhaps less necessity for the sick-room to be cut off from the rest of the house than in scarlet fever, small pox, diphtheria, measles, or chicken-pox; or for keeping the nurse and her clothes away from other members of the household; but the fact that the poison is situated in the bowel-discharges renders the dealing with these a matter deserving of every possible care.

The risk that these discharges will communicate the disease is greatly reduced if proper care be taken to dispose of *all* of them without delay, and if precautions are taken to prevent soiled linen from remaining where it might be a source of danger. But one fact remains: the excreta of a person suffering from enteric fever, if introduced into milk or drinking-water, have a power of self-multiplication which

enables a small amount of matter to poison a large number of persons. No better instance of this can be given than that of the outbreak of enteric fever in the Caterham Valley in the year 1879, where a deep well was polluted by the excreta of a man suffering from this disease while engaged in its repair, resulting in the production of more than three hundred cases of enteric fever amongst those drinking the water.

The precautions which must be taken to avoid any contamination of milk are equally necessary, for since Dr. Ballard first proved that an outbreak of enteric fever in Islington had been caused by milk thus infected, other groups of cases have been found to arise in the same way. It is easy to understand that any one engaged in attendance on a person suffering from enteric fever could by carelessness infect, by means of water used for drinking purposes or milk put aside for the same use, not only herself, but others who might come to swallow it.

Given, then, that the nurse is to be scrupulously clean in her dealings with her patient, is there anything she can do beyond to prevent the excreta from proving dangerous?

This brings us to the question of disinfectants. It has already been stated that we have the excreta chiefly to fear as poison-carriers, and we have, therefore, to direct our attention to the best method of dealing with the excreta themselves, and with articles of clothing which become soiled by them.

Now, the excreta of a person lying on his back with enteric fever are necessarily received in the first instance into a bed-pan, and here is presented the earliest opportunity of dealing with them. Some disinfectant should be placed in the pan before being used, while the surface of the contents should be immediately afterwards sprinkled over with more disinfectant. The bed-pan should always be emptied at once, and then washed with scrupulous care before being put away. Directly the contents of the bed-pan have been emptied down the water-closet, the latter should be thoroughly flushed and cleansed, and the drain disinfected. This is the best method of dealing with the excreta of a person suffering from enteric fever. If every possible care is taken to disinfect them, and the other precautions mentioned be taken, there is every probability that the other inmates of the house will be perfectly safe, provided the drains of the house are correctly made.

But the last supposition implies a great deal more than most houses can comply with, for in no house could enteric fever be treated with certain safety to the other occupants, if opportunity exist for the excreta to remain about the water-closet itself, or the drains leading from it, or if opportunity be given for the air of the drain, which is more or less charged with infection by the passage through it of the excreta, or the possible retention in it, for awhile, of some portion of them, to pass into the house, either through some faulty joint or through the trapping-water of an unventilated drain.

Now, all these conditions may and do occur in very many existing houses. Wherever are to be found water-closets of the "container" kind, there is considerable probability that infectious material will hang about the container; and again, in the majority of houses there is no opportunity for a current of air to pass through the soil-pipe, and thus, owing to the retention of, perhaps, only some very small amount of infectious matter, the air of the soil-pipe becomes charged with

infection, and the trapping-water fails to prevent some portion of the air entering the house.

Not uncommonly there is found in connection with unventilated soil-pipes a trap at the bottom of the soil-pipe, where the excreta remains for a considerable time before escaping into the main drain of a house. There is no doubt that their retention in such a situation, under these circumstances, is a very ready source of danger.

Another risk in connection with the treatment of this disease in houses may be briefly pointed out—viz., the possibility of the water-supply being poisoned by some connection between it and the water-closet or drain which has received the excreta of an enteric-fever patient.

In many houses the waste-pipe of the cistern opens directly into the drain, and thus an up-current may carry up the waste-pipe and into the cistern particles of poisonous matter which will infect the whole volume of water, and when this happens to be used for drinking purposes, the extension of disease is a practical certainty. This arrangement of the waste-pipe has already been sufficiently condemned, and it will not be necessary to refer to it further here.

One other danger must be mentioned before this subject is concluded—viz., the possibility of infection of drinking-water through the supply-pipe to the pan of the water-closet. It has been laid down as an axiom that the pan should be supplied by a pipe coming from a separate cistern, devoted solely to supplying water-closets with flushing-water, and never giving water for any other purpose; unfortunately this rule is not invariably carried out, and in a large number of houses a possibility exists, under certain circumstances, for the poison to be sucked up the supply-pipe into the cistern, or into the mains which also give off branches for supplying water for drinking purposes. This is especially a danger when houses have what is known as a "constant service." With a constant supply there are no cisterns for the storage of water, and the houses should be merely provided with an intercepting supply cistern to each water-closet. When, however, these intercepting cisterns do not exist, a considerable risk is encountered. While the pressure in the supply-pipes is maintained, there is necessarily a tendency to discharge into the pan any poisonous matter which might collect at the mouth of the supply-pipe at the pan; but if for any purpose, such as repairing the mains or the engines keeping up the supply in the reservoirs, this supply is interrupted, a backward current into the mains is likely enough to take place, and by this means any matter situated on the mouth of the supply-pipe to the pan is taken into the mains, where it has opportunity for poisoning a large volume of water, some of which is afterwards discharged along the supply-pipes to situations where it comes to be used for drinking purposes. These are the risks which are ordinarily encountered in houses which have not been constructed in the best way, but it will be understood that if proper precautions are taken enteric fever may be treated in a house occupied by other people with far less risk than any of the other infectious diseases.

The early isolation of infectious cases will be frequently attended with success, but it will be obvious that unless the isolation be begun early, the mischief may already be done; indeed it is sometimes a question whether, if they have been sleeping together, it is worth while to separate a child suffering from measles from his brothers and sisters, for the rash does not make its appearance until

after three days' illness, and the child is undoubtedly infectious before the rash appears. It often occurs, therefore, that other children who have been associated with him have already received infection before they can be separated, although they may not show signs of illness until ten or fourteen days later.

Children suffering from whooping-cough could doubtless be isolated in the same way as persons suffering from the other infectious diseases; but when the length of time during which they would have to be secluded is taken into consideration, such quarantine becomes practically an impossibility. Precautions should, nevertheless, be taken to keep children with whooping-cough away from others.

The next question which arises is that of determining the length of time during which it is necessary the sick person should be thus separated from his fellows—a question which it is not easy to answer definitely. This must, of course, be settled in each individual case, but it may be stated generally that no person ought to be permitted to break his quarantine until he has thoroughly recovered from his illness, and has shed every scab and scale that he has had about him, and has, moreover, had at least half a dozen baths. It is common enough to find in scarlet fever that a period of six weeks elapses between the beginning of the illness and the termination of the shedding of the skin, in some cases this last process not commencing till the sixth week, and, from time to time, persons have been known to communicate scarlet fever to others after eight weeks had elapsed from the beginning of the illness.

The same rule must apply to small pox, the thorough removal of all scabs being the best guide on this point. In measles the period of infectiousness appears to be shorter; and a month is usually sufficient to ensure the freedom from infection of an average case. For enteric fever it may be accepted that as soon as the invalid is strong enough to associate with other people, he may be permitted to do so, but for typhus fever and diphtheria a longer time is necessary.

CHAPTER XC.

DISINFECTION.

Value of Disinfectants—Disinfection of Clothing, Bedding, and Room.

Before closing this section, it is necessary to make some reference to disinfectants; and the first point to be noted is the utter worthlessness of most of the materials to which this name is given. It is common enough to find one or more small saucers placed about the sick-room, and containing some substance which is believed to have some influence in preventing disease, but which either has no action at all, or whose influence is limited to making an odour which, by its strength, overpowers any other odour that may be produced in the room; or it may have an influence in preventing decomposition if any animal substance fall into it; or, again, it may even act as a destroyer of infection if the infective particles should come in contact with it, but the extent to which it is useful in this respect is so limited that it is hardly worth while to set such a trap to catch the few "germs" which thus may perhaps be destroyed. *The average so-called disinfection is a delusion,* and the amount of money which is squandered upon buying substances which are called disinfectants had often far better be spent in soap and water.

Very many of the substances sold as disinfectants are useful as deodorants or antiseptics, and to this extent may be relied upon; but it will not do to assume that everything that prevents smell or prevents decomposition will necessarily destroy an organism which already exists.

It is a matter for very considerable regret that there is so little exact knowledge on the subject of disinfection, particularly because, for want of it, people are constantly relying upon processes which are absolutely valueless, and which tend to give them a false sense of security. The only trustworthy method of estimating the value of any substance as a disinfectant is to mix it in known quantities with another substance which we know without it would give rise to disease; and then, by direct experiment, to learn whether the action is prevented by this admixture. A limited number of experiments in this sense have been conducted by Dr. Buchanan Baxter. It would be out of place here to discuss them in detail, but we will note that permanganate of potash (Condy's fluid) rendered vaccine lymph inert when the mixture of lymph and permanganate contained ·5 per cent. of the latter. So, again, when free chlorine to the extent of ·1633 per cent. was introduced into the inoculated lymph, this proved barren; carbolic acid, in the proportion of 2 per cent., had the same result.

Exposure of dry lymph to chlorine gas for thirty minutes rendered the former inert, to sulphurous acid for ten minutes, and to vapour of carbolic acid for sixty minutes. Experiments with the virus of infective inflammation showed that carbolic acid in the proportion of 1 per cent. or more, sulphurous acid in that of 2·9 per cent. or more, and permanganate of potash in that of ·05 per cent. or more, are capable of so modifying the virus as to deprive it of all infective

power. Similar experiments with glanders poison appear to show that its infective power was destroyed by the addition of 2 per cent. of carbolic acid, or of ·4 per cent. of sulphurous acid.

These are the minimum proportions which have proved of any value. The absurdity, therefore, of trusting to the emanations given off by little saucers or trays full of these materials placed about a sick-room is sufficiently obvious. Disinfection thoroughly carried out is doubtless of value, but, as will be seen, the value is dependent upon thoroughness.

In practice, we have to deal with two sets of circumstances—the one, where the sick person is alive and still ill; the other, where death or recovery have terminated the illness. In the former, it is impossible for us so far to impregnate the air of the sick-room as to destroy the infection which is being given off by the invalid, without doing him considerable injury. We must, therefore, limit ourselves to dealing with infectious articles—such as his excreta, soiled linen, &c., as well as the garments of those who are in attendance upon him. All linen should be steeped in a solution of carbolic acid and water. Carbolic acid is of varying strength. That generally used is Calvert's No. 5, which before mixture contains 98 per cent. of acid. One table-spoonful of the liquid acid in a pint of warm water, or half a tea-cup in a gallon, is a proper proportion for this purpose.

The excreta and linen soiled may be deposited in a solution of sulphate of iron (green vitriol), made by dissolving one ounce of the sulphate in a pint of water. The sheet hung over the door, to which reference has already been made, may also with advantage be kept moistened with carbolic acid, of the same strength as that in which linen is to be steeped, and the water-closet should be flushed with the same material.

The disinfection of the room at the conclusion of the illness can be best effected by burning on an iron tray a quantity of flowers of sulphur, from a quarter to half a pound being sufficient for an ordinary bed-room; but before this is done the fire-place must be closed, and the cracks in the window-sills pasted up to prevent the escape of the fumes. A live coal is then dropped upon the sulphur and the door closed and pasted up in the same manner as the windows, and the room left in this condition for some hours. Subsequently the windows are opened, and left open for two or three days and nights, the walls stripped of their paper, and the floor, paint, walls, and ceiling thoroughly cleansed, so that no hole or corner shall remain in which dirt may linger. Everything in the room must be regarded as infectious; chests of drawers must be opened, cleared of their contents, and the interior of the drawers and cupboards exposed to the action of the sulphur fumes; all linen articles will, of course, be treated as already described, but beds and woollen material must be separately dealt with. For these there is no other remedy than that of heat, and either the aid of the sanitary authority of the district should be called in for this purpose, or the articles should be sent to one of those firms who make disinfection their business, or else they should be destroyed by fire.

We have referred to thoroughness of disinfection being necessary, but this word must not be limited in its application to the character of the disinfectant or the length of time during which it is permitted to act upon the infected article; it is equally important that no single garment, book, or toy should escape this treatment. It is the constant experience of those who have to do with infectious persons to know of

families being inconvenienced by, and money expended upon, the disinfection of a house, and for some small object to escape from the purification to which everything else was subjected, and for disease to recur as the result of this omission. Thus, it is recalled to the writer's recollection how, on one occasion, a child's whip through such an accident gave rise to a fatal attack of scarlet fever in a younger brother of the child who was first attacked. Life is too easily destroyed by this unseen poison, to warrant the least negligence in the important duty of disinfecting an infected house.

We have discussed the precautions which are to be taken to prevent the sufferer during his convalesence from giving rise to further disease amongst his house-mates; we may also have to consider how the latter may be still protected should his illness end in death. On this point little need be said, but wisdom teaches us we should not cling too fondly to all that is left of our companion, or delay too long its removal to the earth, which sooner or later must claim us all.

In our varying climate it is impossible to lay down any hard or fast rule as to when burials should take place, but it is well that the few hours which intervene between death and the grave should be as short as possible. If death have resulted from an infectious illness, it is very desirable that it should be recollected that infection will still remain about the body, and that its removal to another room than that already infected will increase the risk to others. It is far better for it to remain where death has taken place. There, in a cool room, with the windows open and with the door closed, there is least opportunity for harm to happen, an opportunity which is further diminished by the early closing of the coffin which receives the dead.

It is by being prepared that we may best be able to cope with the illness which is sure sooner or later to invade our most healthy home; and by knowing how we ought to tend the sick we may give him the greatest aid to recovery, while we prevent other inmates of the house from sharing his misfortune.

If this duty be undertaken thoughtfully and intelligently, we shall go far to make the home that place of safety from ill health which it is the intention of our book to create.

LEGAL LIABILITIES.

By Thomas Eccleston Gibb.

CHAPTER XCI.

Rates and Taxes: by whom they are made and collected, and for what purposes they are applied—Valuation of Property for Assessing Rates and Taxes—Gas and Water Rates—Roads and Sewers—Liabilities under Leases and Annual and Shorter Tenancies.

The term rates is usually applied to imposts raised for local purposes, and taxes to such as are raised for Imperial purposes, although rates are also generally spoken of as local taxation. The rate for the Relief of the Poor is the basis of all other rates, and is the oldest form of local rate in England. Its history may be traced to the Anglo-Saxon period, but the foundation of the present system of poor rates and poor laws is generally dated from the reign of Elizabeth. The churchwardens and overseers of every parish in England and Wales were directed by the Act of Elizabeth to put to work those of the poor who could work, to apprentice children, and to find necessaries for the poor, lame, impotent, and blind; and they were further directed to tax every inhabitant and occupier of property, to meet the expenses incurred, according to their ability to pay.

The Borough Rate leviable under the Municipal Corporations Act is made upon the parishes or townships in the boroughs according to a certain pound rate fixed from time to time by the council, on the full and fair annual value of the lands, tenements, and hereditaments rateable to the relief of the poor therein, in like manner as the County Rate. The council may order the overseers to pay a Borough Rate, or a "Watch" or Police Rate out of the Poor Rate, or to make a separate rate for that purpose. In like manner the rates made for School Boards, Burial Boards, Baths and Washhouses, Public Libraries and Museums, and for paving, lighting, and sewerage, are levied by or in the same manner as Poor Rates are levied, by overseers.

The term Poor Rate always includes more than simply the expenditure for the relief of the poor. For example, such expenses as are incurred in the registration of Parliamentary voters in counties and boroughs, the making of Jury Lists, the registration of births, marriages, and deaths, the enforcement of the compulsory vaccination laws, are always payable out of the Poor Rate. Beyond these many other liabilities—as the expenses of Highway Boards, County Justices, Commissioners of Baths and Washhouses, Burial Boards, Sanitary Authorities, Lighting and Watching Authorities, and School Boards—are in some cases charged upon the ratepayers as "Poor Rates," instead of as separate rates. There are in England and Wales more than 27,000 separate authorities exercising some description of control over the making, collection, and expenditure of rates amounting to fifty million pounds (£50,000,000) sterling per annum, and it is just as impossible to give any clear detailed description of the various functions of these authorities, as it would be to make such a description interesting to the general reader.

Ratepayers too often look upon the payment of rates as a burden, and not as a means of obtaining in the readiest way many of the principal advantages of civilised life. A glance at the purposes for which rates are made, will suggest the loss which every one would suffer if the state of society were such that these purposes had to be provided for by individual effort, even if such a state of society were possible. The County Rates and Police Rates provide for the control and custody of criminals and lunatics; the Poor Rate proper provides for the relief of the sick and aged poor, and the maintenance and education of destitute children; the Borough Rate in Corporate Towns and the Metropolis Management Rates in London provide for such requirements as paving, sewerage, lighting, water supply, cleansing and improvement of thoroughfares, the execution of sanitary regulations, the establishment and maintenance of public buildings, works, markets, museums, libraries, the supervision of food supply and of weights and measures, and many other matters; Burial Board Rates provide for public cemeteries; and rates provide also for baths and washhouses, docks, harbours, navigations, embankments, maintenance of highways, bridges, &c., and for education.

Imperial taxation has the advantage of uniformity, at least in the mode of its assessment and collection, although open to some of the same objections as local taxation as regards its incidence. The term "Imperial Tax" may be fairly defined as expressing the exaction of money from the individual for the service of the State as distinct from a rate being the exaction of money for the purposes of the locality in which the individual is placed. There are, however, so many Imperial necessities provided for by local rates, and so many local requirements paid for, or partly paid for, out of Imperial taxes, that a complete definition of tax as distinct from rate is not possible.

Chancellors of the Exchequer have vied with each other in the effort to make taxation a practical art. As Turgot said, "the art of plucking the goose without making it cry." Indirect taxation is the chief expedient to this end. Indirect taxation is a duty levied upon an article before it reaches the consumer. The merit of this system is that the immediate burden of the tax does not fall upon the person who pays it, but he acts merely as a collector from the consumer for the State. Tea, tobacco, and wine duties are levied upon the importers, and the only check to this source of revenue is that an excessive duty may limit the consumption of the article so as to reduce the revenue. No doubt indirect taxation on luxuries, and especially on those which may be used to vicious excess, has strong recommendations. A tax on the necessaries of life cannot in any way be good for the individual, as it is a tax which he cannot avoid, and which increases in its oppression with the increase of his necessities. The tax on salt was one of the chief causes of the French Revolution, and the agitation which preceded the repeal of the Corn Laws in England was one of the most anxious times for English politicians. The happiest condition for the revenues of a country is when luxuries are so abundantly used by all classes that a small addition to their price is a slight burden, yet yields a large revenue. In this country the revenue thus derived exceeds thirty millions per annum.

The chief taxes which now form the revenue are (1) assessed taxes, (2) property and income-tax, (3) customs duties, (4) excise duties, (5) stamp and post-office, and (6) land tax. Assessed taxes are taxes leviable upon inhabited houses, and upon servants, carriages, horses, armorial bearings, &c. Property and Income Taxes are

direct taxes levied upon the receipts derived by the individual from houses, lands, trade, office, or employment. Customs duties represent the tax upon commodities imported from abroad, and form a large source of the revenue of the country. The right of the Crown to certain imposts by custom shows the origin of the term, but since the control of this part of the taxation has, like the rest, come to be dealt with by Parliament, and since free trade legislation has cleared away a great mass of the burden on the commerce of the country, customs duties have ceased, to a large extent, to act as a prohibition or discouragement of the importation of necessary commodities, and have, by the simplification and reduction of tariffs, supplied an enormous amount of the revenue. The Excise is nominally a tax upon a commodity *cut off* before the article reaches the consumer—a drawback from the price which the consumer is required to pay upon the manufactured article. The chief source of revenue under this head is the duty upon alcoholic liquors. Many excise duties have of late years been abolished. Stamp duties and postal charges are a convenient mode of raising revenue by the legal acknowledgment of private deeds and instruments of every description, and by the transmission of private communications. This is a comparatively modern contrivance for raising revenue, having been first instituted in the reign of William and Mary. Land tax is an old description of tax of most irregular incidence. It is imposed on houses and land, and has taken the place of ancient subsidies formerly known as scutages, talliages, tenths, &c.

The principle of valuing property for the purposes of assessing rates and taxes upon the individual, is the same for all purposes, both Imperial and local, except that Imperial taxes are levied upon the "gross value," or "gross estimated rental," or *gross* "annual value," which is the rental value exclusive of rates and taxes, but inclusive of the cost of maintaining the property; whereas the local rates are levied upon the "rateable value," or the *net* "annual value," which differs from the higher value by excluding the cost of maintenance, insurance, &c. This may be most simply illustrated by examples. Three houses, structurally equal, and in all other respects of equal value for the purposes of rates and taxes, may be let in various ways; but most commonly they would be let in one of the following ways, subject, of course, to other conditions as might be agreed:

CONDITIONS OF TENANCY.

1.

The landlord undertakes:
(*a*) To give possession in consideration of rent.
(*b*) To keep the premises in repair and to pay insurance.
(*c*) To pay all rates and taxes.

The tenant undertakes:
(*d*) To pay rent.

2.

The landlord undertakes:
(*a*) To give possession in consideration of rent.
(*b*) To keep the premises in repair and to pay insurance.

The tenant undertakes:
(*c*) To pay all rates and taxes.
(*d*) To pay rent.

3.

The landlord undertakes:
(*a*) To give possession in consideration of rent.

The tenant undertakes:
(*b*) To keep the premises in repair and pay insurance.
(*c*) To pay all rates and taxes.
(*d*) To pay rent.

The first case illustrates the usual conditions upon which property is let to weekly or monthly tenants; the second the conditions applied to annual tenancies or agreements for periods not exceeding three years; and the third to leases.

In each case the full value of the premises, including rent, taxes, repairs, and

insurance, being taken at £60 per annum, the valuation for the purpose of assessing rates and taxes may be thus shown :—

In the first case the valuation is arrived at thus :

Rent paid to landlord	£60	
Deduct rates and taxes included in rent, and upon which rates and taxes cannot again be charged . . .	15	
	£45	Gross value upon which Imperial taxes are assessed.
Deduct repairs and insurance . .	7	
	£38	Rateable value upon which local rates are assessed.

In the second case thus :

Rent paid to landlord	£45	Gross value upon which Imperial taxes are assessed.
Deduct repairs and insurance . .	7	
	£38	Rateable value upon which local rates are assessed.

In this case the total paid by the tenant is, as in the former, £60, viz. :

To the landlord	£45
For rates and taxes paid by tenant	15
	£60

In the third case the valuation is made thus :

Rent paid to landlord	£38	Rateable value upon which local rates are assessed
Add repairs and insurance which are cluded in "gross value" . . .	7	
	£45	Gross value upon which Imperial taxes are assessed.

In this case the total paid by the tenant is the same as in the two previous cases, viz., £60 :

To the landlord	£38
For repairs and insurance	7
For rates and taxes	15
	£60

It is assumed in each of these illustrations that the rent paid is a fair one in consideration of the conditions named ; and therefore, if the reader compares the assessment of his own house with what is said above, he must further consider whether the rent paid under lease, agreement, or short tenancy is the fair rent of the premises at the present time. It may be, for example, that a house may be held on a lease granted many years ago, or under other conditions so favourable to the tenant that the rent paid under the lease does not represent the actual value if the premises were now in the market. It is on this point that the chief difficulties arise in assessing property for the purposes of rates and taxes. The duty put upon the authorities is to assess according to the value at the time the valuation is made ; and the usual objection of the occupier is that the rent he pays, and has paid, perhaps, for many years, and under much less favourable conditions than now exist, is a fair rent, notwithstanding it may be urged that other similar property has recently been let at much higher rentals, and that it would be unjust for the new tenants in a district to be taxed higher to meet the deficiencies in the amounts paid by the old or more favoured tenants.

Under the provisions of the Parochial Assessment Act, the Union Assessment Act, the Valuation (Metropolis) Act, and other such Acts, the valuation of property

is made by overseers of the poor, with or without professional assistance, and the values ascertained by them, frequently under the most crude and unsatisfactory conditions, are inserted in Valuation Lists. These lists are subject to revision by Assessment Committees, appointed generally by Boards of Guardians, but in a few cases by other bodies; and their decisions may again be revised by the local justices, or by the High Court of Justice. In the metropolis, and in other largely populated areas, the work is well done, considering the drawbacks inherent in the complicated system devised for doing it; but in many parts of the country the Valuation Lists are most unsatisfactory. The Assessment Committees take little trouble. No objections are made in many cases, because every one is originally assessed by the overseers at much lower than he ought to be; and all the Union Committees strive after is to prevent one parish being assessed considerably below what it ought to be, and so as to be disproportionate with the other parishes of the Union. In some parishes, the gross estimated rental represents fairly the rental value for the purposes of Imperial taxes, and the Assessors and Surveyors of Taxes take the figures of the Valuation List for the purposes of the assessment for Imperial taxes; in other districts the gross estimated rental is but two-thirds, and even one-half, and in individual cases not more than one-third what it ought to be, and the Valuation List is ignored for the purposes of Imperial taxes, or if it is taken, as is the case sometimes, as a basis, the result is that the district is largely favoured as regards its contributions to the Imperial Exchequer through the neglect, ignorance, or design of its local overseers and assessment committees. There is no doubt that this bad administration of the law leads to unfairness, by forcing the trading classes of large towns, who contribute most largely to both local and Imperial taxation, to pay, in addition to their own heavy burdens, a part of those which ought to be borne by others.

The Valuation Acts, as in force in the metropolis, contain many improvements on the Acts as applicable to the rest of England and Wales, especially by the introduction of the Government Surveyors of Taxes to assist the Assessment Committees in securing uniformity as between one district and another. At first there was a certain amount of jealousy exhibited because of the apparent encroachment of centralization, but all such feeling has now ceased, and great advantage is seen on both sides from the fact that the Imperial and local officers are engaged in assisting each other in producing a result which has the effect of assisting in securing uniformity. Setting aside the consideration of the exceptionable position of the metropolis, in this and other details, the general system of assessment may be thus described :—

The overseers of a district make a list called a Valuation List, which contains in respect of each rateable hereditament the name of the occupier, the name of the owner, the situation of the property and its extent, the gross value or gross estimated rental, and the rateable value. The List is then deposited in some public place, and notice of such deposit is given by the overseers. A copy of the List is sent to the Assessment Committee of the district for revision, and any objections made to any entry in the list is heard by the Assessment Committee.

The Assessment Committee may also hear the objections of parish against parish on the ground that a whole parish may be undervalued, and so be trying to evade its proper contribution to the Union charges. A new valuation is made "from time to time," generally when the overseers or the Assessment Committee see fit, except

in the metropolis, where an entirely new list is required to be made every five years. If a ratepayer objects to the amounts fixed for any hereditament, he may send notice of objection to the Assessment Committee, and as a rule he is required to attend and support his objection by evidence. It is very seldom that any one formally objects to a neighbour's assessment. He may refer to it as an argument for the reduction of his own, and although it may be a clear case where the neighbour's assessment should be raised and his let alone, for the sake of the uniformity nominally sought after, this would not satisfy an objector, but on the other hand would place him in a position as regards his neighbour which few would care to occupy. At the time of the passing of the Metropolis Valuation Act, it was urged that the objections of persons to the assessments of other persons' houses, and for making which increased facilities were given, would afford great assistance to Assessment Committees in arriving at uniformity, but the result has not proved this to be the case. On the other hand, as an example, it may be said that in one of the largest London parishes, where, since the passing of the Metropolis Valuation Act in 1869, there have been at the several revisions at least a total of 20,000 objections, not more than six ratepayers have given notice of objection to assessments other than their own, and only two of these have attended to support their objections.

This shows clearly that the machinery should be so complete in itself, and entirely under such control, as not to require that one ratepayer should put himself in antagonism to another before he can obtain the justice which his case and the state of the law demands. In many parts of the country gross inequality is the rule and not the exception. There are cases where the struggling tradesman of a small town pays on a full assessment for his house and shop, because his premises are assessed according to his actual rent, while his landlord, who occupies the mansion and park close by, is not assessed at one-fifth of what he ought to be; but who is to object before the Assessment Committee, composed of, perhaps, a few tradesmen and farmers, with the landlord himself acting as chairman? It may be said, therefore, that, in dealing with the question of assessment, the reader should, under the present system of administering the law, take the trouble to examine the Valuation List of his parish from time to time, not only to see that he is not over-assessed, but to see that he is as much under-assessed as his neighbour, so that if he has any grounds of objection, he may make them to the Assessment Committee.

The great railway, canal, gas, and water companies, as well as miners and large manufacturers, profit largely by the present lax system of administration, and are thus able to throw upon those ratepayers who occupy small premises at rack rentals and on short tenancies a large share of the burdens which they themselves ought to bear. Often the overseers of a parish leave a large property at half its value on their books, for no other reason than that they are not competent to assess it, and are too "economical" to pay for professional assistance. The so-called "economists" are, in this and many other ways, generally the most costly luxury which the ratepayers enjoy under the present systems of local self-government.

Gas and water rates are not rates in the same sense as other rates. They are charges made for articles supplied, although in the case of water the charge is usually made upon an assessment of the property, made in a similar manner, if not following the value fixed by the Valuation List. This mode of assessing water rates claims to

have advantages over the meter system, especially on sanitary and public health grounds, and limits in some degree the objection of taxing a necessity of life, for the benefit of the shareholders of private companies. Water rates are assessed upon the annual value of houses, and the Acts of some of the principal companies fail to define annual value, so that there are frequent disputes on this question. Objection to an excessive assessment to water rate is made to the company, and as the rate is made up of several items—viz., a per-centage on value, with additions for baths, water-closets, gardens, &c.—it is always better, before objecting, to ask the collector or the secretary of the company for an explanation of the charge when it is thought to be excessive.

Gas rate, as it is called, simply means the rate per 1,000 cubic feet at which the gas is charged in any district.

Roads and sewers, once made and "adopted" by the local authority, or "dedicated" to the public, and this dedication accepted, are to be maintained by the public authority. Householders are liable to pay the first cost of making roads and sewers, and to pay, as well as the first cost, the cost of the maintenance of the separate house drains. When roads are kept as private roads, and the cost of maintenance defrayed by the owners or by the occupiers of the houses abutting on such roads, such occupiers are not relieved from the ordinary charges for the maintenance of public roads, so that the policy of the law is to discourage the formation and maintenance of private roads. Moreover, there are very great objections to private roads, unless they are thoroughly well made and maintained by the owners. Newly-formed roads are sometimes retained by the owners for the sake of securing, as they say, a less town-like appearance to the streets, and thus improperly paved and badly drained streets are formed, which often lead to damp and unhealthy houses; the real object having been to save the builder the cost of making the roads until he has sold his houses, and so to distribute the inconvenience and cost upon the poor house-buyers, who have no remedy until, with their united grievances and at much greater cost than would have been originally necessary, they induce the local authority to properly make and drain the road, and adopt it as a public road. House-buyers should always, before buying a house in a new neighbourhood, inquire at the office of the local authority whether the road has been "adopted," and whether all charges for road and sewer construction have been paid.

The sanitary authority of the district should always be communicated with in the case of drain or sewer defects. There is no part of a house where builders are so likely to "scamp" their work as the drainage, and they are, probably, in that point under the least amount of supervision by public authorities. A local surveyor may order the work to be done in a particular manner, but the work is done and covered up in his absence, and the nicely-worded bye-laws which hang in the builder's office are not more likely to be looked at by the builder than are the drains, when buried beneath the ground, by the officer appointed to see those bye-laws carried out. Nothing short of an alteration of the system can remedy this great sanitary defect. No sewer or drain should be made outside any private premises except by the local authority, and the drains inside should be subjected to periodical supervision, and there should be a manhole trap or junction separating the public from the private drainage immediately outside every house. By this means evils created within a house would, at least in the first place, be confined to the inhabitants of the house;

and on complaint of any inhabitant (and this is of great importance in the houses of the poor, where there may be several families), the local authority, being first satisfied that the defect does not exist in the public part of the drain, should be authorized to repair the internal defect, and charge the cost upon the landlord.

A tenant may hold or occupy any land, houses, or tenements, by any right or title, as owner, or at a rent for life, years, or other term, or at will. A landlord meant originally the owner of the land. Now, in all general matters relating to landlord and tenant, it may be taken that the landlord is the receiver of the rent, and the tenant the one who pays, so that the landlord of the actual tenant is the tenant of a superior landlord, and this state of things goes on until, in some cases, there are half-a-dozen or more persons who are thus both landlords and tenants between the actual tenant and the owner of the soil. Houses occupied by the poorer classes in large towns are often let by the week or the month, but generally houses and lands are let by the year, or for three years by agreement, or on lease for a longer term by deed, at a reserved rent. When the property is let on lease, the landlord's whole interest is demised, subject to certain conditions. The Statute of Frauds requires a lease to be in writing; and by a more recent Act such writing must be in the form of a deed, sealed and delivered. It is important to notice that a leaseholder who accepts the demise of a house is liable for its repair and maintenance, and has no claim upon his landlord unless such be specially agreed, even if he finds the house to be uninhabitable. Even agreements for shorter terms do not, in the absence of express covenants, require the landlord to keep the premises in repair, although, where there is no demise, the landlord as a rule, in his own interest, at least sees that the roofs and outer walls are kept in good repair.

Agreements for from one to three years should in the interest of the tenant contain covenants whereby the landlord agrees to keep the roofs, external and other walls, in good substantial repair, and "wind and water tight." If the house is put in good repair, the tenant should agree to keep up the interior—namely, the doors, windows, shutters, locks, bolts, bars, and other fastenings, bells, and fixtures upon the premises. A yearly tenant, or a tenant for three years, usually covenants to deliver up the premises at the end of the tenancy in as good a state and condition as when he entered, "fair wear and tear excepted." Sometimes landlords agree to do all repairs, both internal and external. Whatever the landlord undertakes to do in the way of repairs the tenant can enforce the fulfilment thereof, but non-compliance on the landlord's part to execute a covenant does not prejudice the liability of the tenant to pay his rent. Before taking possession of a house, the intended tenant should inquire what the house is assessed at in the Valuation List, and have some proof that the rates and taxes are paid to the date of the commencement of his tenancy, otherwise he may have some trouble afterwards. A new tenant is only liable to pay rates from the commencement of his occupation, but some taxes can be enforced from the tenant in possession, although due prior to his becoming the occupier. The ground-rent of a house is also recoverable from the tenant in possession if the landlord has made default in payment. An agreement by word of mouth to take a house or land cannot be enforced until a tenancy is created and actual entry upon the premises made in pursuance of such agreement. Tenants under a lease for years are entitled to hold the property until the end of the term, unless they break any of the conditions and covenants of the lease. A tenancy

agreed between the parties to be a yearly tenancy is a common mode of letting without written agreement. This agreement can be terminated at the end of the first year, or by notice to quit at the end of each succeeding year. The notice must be given before the commencement of the six months which end with the current year. A tenancy at will is nominally a tenancy revocable at the will of the landlord, but the term is usually applied to an annual tenancy where there is no written agreement. This is the case, no doubt, because the payment of any portion of a yearly rent converts such a tenancy into a yearly one. A tenancy at will is seldom of long duration. A tenancy for a year, and "so on from year to year," is a common form of written agreement for a yearly tenancy. It differs only from an ordinary yearly tenancy in that it cannot be terminated until the close of the second year. It is a tenancy for a year without the power of giving six months' notice to quit during the first year. A tenancy on sufferance is where a tenant wrongfully holds possession after the expiration of a lawful tenancy, and ejectment can be maintained against him without any previous demand of possession, as required in the case of other tenancies.

A person granting a lease is termed the lessor, and the person accepting the lease the lessee. A lease vests the use and occupancy of premises in the lessee for a certain term, in consideration of a stipulated annual rent to the lessor, and of the performance of other covenants. Leases are usually granted for seven, fourteen, or twenty-one years, determinable at the end of either of the two first-named periods, at the option of the lessee only. Although this is the usual mode, sometimes the option is on both sides. A lease should contain a schedule of fixtures to be surrendered at the end of the term. This is very frequently omitted, although far more essential in preventing dispute afterwards between landlord and tenant than the long and tediously worded leases now no longer necessary, except as a justification for solicitor's charges. It is still usual, on requiring a lease, to enter into and sign an agreement containing the usual and any other special covenants desired in the intended lease. An agreement for the lease of business premises is sometimes taken with the view of giving a tenant the option of testing the suitableness of the premises. In such a case the tenant should see that the agreement contains a distinct clause terminating it at a particular period, with the option of taking the lease. An agreement for a year or for three years, with the option of a lease at the same rent, is not an uncommon form, and is specially suitable in the case of a person taking a shop in a new neighbourhood. Leases are prepared in counterpart, and should be executed by being signed, sealed, and delivered. It is not necessary, although it is usual, to employ a solicitor to settle a lease. If the person does not understand sufficient to act for himself, it is always better to employ a solicitor than entrust such business to unprofessional agents. Underleases are leases granted by persons who are themselves leaseholders and not freeholders. Formerly aliens could not take leases, but now they can, and under a recent statute they may take, acquire, hold, and dispose of real and personal property as if they were natural-born subjects. This provision does not, however, qualify an alien for any franchise. If a lease be lost, the tenant's term therein will not be affected on his proving that such term was not expired. If a lease or any other such deed or document be lost, an attested copy should be obtained if possible, or if that be not possible, then a statutory declaration as to the contents of the lost deed may save trouble afterwards. Much

of what has been said above applies to all leases, and is not confined only to leases at rack rentals for seven, fourteen, or twenty-one years. Any person can grant a lease of whatever property he possesses, unless he is under some legal disability. The owner of an entailed estate, or an estate for life, has power to grant a lease not exceeding twenty-one years. A person who is the absolute owner, or who is said to possess the fee simple, may lease for any number of years, or for a life or lives, and a lessee for a certain number of years, or for a life, may, unless forbidden by the terms of his lease, in like manner grant an underlease.

An owner of land in fee simple who may wish to have such land utilised as building land usually adopts one of the following courses:—(1) A building agreement with a contractor to erect houses on terms agreed, and when completed to grant leases at rack or full rentals. (2) A building agreement under which the builder pays the cost of building, the owner reserving a ground-rent. In this case the builder may, unless forbidden, grant underleases and create "improved" ground rents. (3) A conveyance of the land in fee for building in consideration of a rent-charge, and (4) an absolute conveyance with or without building restrictions. In large centres of population, and especially in London, the lease at a ground-rent is the usual form, and it is not uncommon to have several underleases existing between the original leaseholder and the actual holder at a rack-rent. Where there are several underleases between the freeholder and the beneficial occupier, it is most important that such beneficial occupier should know the extent of his liability under the intermediate leases, and take care that he is not governed by covenants, the extent or even existence of which may not be brought to his notice unless required. Any lease may be assigned to a third party, but unless the freeholder or other lessor is a party to such assignment, or accepts the assignee subsequently, the original lessee is liable, notwithstanding the assignment.

Persons letting and taking apartments or lodgings, whether let furnished or not, are in the ordinary relation of landlord and tenant, and it is always better, for mutual satisfaction and to avoid disputes, that there should be a written agreement which should specify the amount of rent, the time of entry or commencement of payment of rent, the length of notice to quit required, and such other particulars as the case may require. If the apartments are furnished, a schedule of the furniture should be added to the agreement, as in the case of a furnished house, and in both cases all defects, cracks, &c., should be carefully noted. If there be no written agreement, the length of the proper notice to quit depends upon the term of letting or payment of rent. If the letting be at so much per week or month, then a week's or month's notice is required, but if it be at per year, although payment is made quarterly, the same notice will be required as in the case of a house. If there be a custom, as is the case in watering places and some large towns, the length of notice is regulated by such custom in the absence of written agreement. If a tenant go without notice, the landlord may recover rent, although he may advertise for another tenant, but cannot recover rent subsequent to a letting to another person. Compensation can be recovered for wilful damage done by tenants of houses or lodgings. Rent may be sued for in a county court, as well as levied for by means of distress.

CHAPTER XCII.

How to choose a House for Purchase—Registration of Births, Deaths, and Marriages—Sanitary Laws and Administration—Analysis of Food, Drink, and Drugs—Inspection of Weights and Measures—Public Offices : Mayor, Alderman, Councillor, Guardians of the Poor, Vestrymen, Members of the School Board, &c.—Registration of Jurymen and of Parliamentary and Municipal Voters.

In an earlier part of this book something has been said on the importance of choosing a house for purchase or residence, but having chosen it, after examination as to style and character of building, its sanitary arrangements and neighbourhood, it has to be considered as an investment. A new house in an unsettled neighbourhood is a much more doubtful speculation than an older house in a neighbourhood not surrounded by uncovered building land, and this is even more risky if the land be freehold. Many a person has purchased a pretty freehold villa, with neat garden, and then found his property reduced to half its value in a few years by the adjoining plot being let for a block of labourers' dwellings or a court of small tenements. Where freehold property is purchased, the purchasers should carefully inquire as to what, if any, restrictions there are upon it and upon other freehold property adjoining. A man may build his house and lay out his plot of garden so as to get a nice view, and find in a short time his view intercepted by a slaughter-house or a factory. In this, as in many other respects, local government, like local taxation, requires very considerable improvement to make it equal to the necessities of the people of this country. If a man be destitute he has a right to receive from the guardians of the poor of his district proper food, shelter, and clothing, whether in sickness or health; but if he be not destitute he may, under the direst necessity, be housed in an insanitary or even pestilential dwelling, fed on the most unwholesome food, and clothed in infected clothing, and his house may become a centre of infection in a neighbourhood. It is true there are public health authorities, but these authorities are used too often for other and more selfish purposes. When these authorities are, as they often are, *controlled by the active owners of small property*, the caterer of unwholesome food, or, above all, that great local man, the "economist," it is very hard to do much for the poor. The "crotchets of doctors" are condemned as "new-fangled" by men who speak of their forefathers as never having suffered from bad smells and bad water.

Sanitary regulations are the most difficult, as they are the most necessary to enforce. What are called the principles of local self-government are principles unknown to science, and science is equally unknown and disregarded by those whose chief notions of government are comprised in the phrase, non-expenditure. The story of the surveyor asking for a level, is only an illustration of the intelligence of "*boards*." The chairman, who was a farmer, said "he knew that he expressed the views of the Board in condemning the extravagant notions of the new surveyor" who had asked for a level, "and hoped the surveyor would understand that when he wished to try the level of the road he must not be above going on his knees

and looking along the ground, as they always did in their business." Town boards, as well as country boards, are governed chiefly by the cry of low rates, whilst probably nothing leads so much to high rates in London and other large towns, as the non-expenditure of so-called economists, and the neglect of *necessary* works. There are men in London who *pose* as local economists, and are invariably returned at the head of the poll at election times, who are a distinct fraud on the public, and whose "economy," as it is called, costs the public thousands of pounds a year. This is chiefly caused through the want of any real interest amongst people generally in local affairs.

Registration of Births and Deaths was introduced in 1836. Information of a birth should be given to the Registrar of the district in which the birth takes place within forty-two days after the birth by the father or mother of the child, or in their default by the occupier of the house in which the birth occurs, or a person present at the birth, or the person having charge of the child. It is the duty of every registrar to inform himself of the occurrence of births within his district, and to register them without charge at his office or in any public institution. The Registrar is however entitled to a fee of one shilling from the informer for registering a birth if he attends at the place of birth or at the informant's house. In default of information within forty-two days after birth, and before the expiration of three months, a Registrar may, by written notice, require any competent person to come to his office to register a birth. After the lapse of three months, and before the expiration of twelve months, a birth can be registered only in the presence of the Superintendent Registrar. Upon such registration the Superintendent Registrar, as well as the Registrar, is entitled to a fee of two shillings and sixpence, and certain formalities have to be attended to, so that there are both extra expense and delay in neglecting this simple duty. After a year has elapsed no birth can be registered except by the written authority of the Registrar-General, and then only upon payment of still higher fees to the Superintendent Registrar and the Registrar.

The death of every person dying in England is required to be registered. When a person dies in a house, the informant should be the nearest relative present at death or in attendance during the last illness, or in default of these any other relative in the same sub-district, or a person present at the death, or the occupier of the house, or any inmate of the house, or the person causing the body to be buried. If a death does not take place in a house information is to be given by any relative knowing the particulars, or a person present at the death, or the person finding or taking charge of the body, or the person causing the body to be buried. In the case of a coroner's inquest, the jury are to inquire the particulars required to be registered concerning death, and the Coroner is to send a certificate of the finding of the jury to the Registrar within five days. Information of a death should always be given within five days, and should be accompanied by a medical certificate. In places where the Registrar is at a distance, or there are other difficulties in the way of giving information in person, an informant may send a preliminary notice in writing and the medical certificate, and in that case the time for completing the registration may be extended to fourteen days. It is the duty of the Registrar to inform himself of any occurrence of death in his district, and if informants fail to give information he may, after fourteen days, and within a year, require such informants to come to him

to effect the registration of death. Any registered medical practitioner must give a certificate of the cause of death if he has been in attendance during the last illness, unless the case is referred to the Coroner. In that case the Coroner's certificate will take the place of the ordinary medical certificate. The medical certificate must always be taken by the informant to the Registrar on the registration of the death. The Registrar's certificate of registration or the Coroner's order for burial should in every case be delivered at the time of burial to the person officiating. If for any reason the person officiating buries a body without either the Registrar's certificate or the Coroner's order, he must give notice to the Registrar, otherwise he is liable to a penalty. So also the person who ought to have produced such certificate or order will be liable to a penalty. There are penalties, too, for improperly registering births and deaths, and the Superintendent Registrar of a district is empowered to prosecute persons guilty of any offence under the Registration Acts. There is in every district a Superintendent Registrar of Births, Marriages, and Deaths, and to him application may be made for any information on these subjects. Each district is divided into sub-districts for the registration of births and deaths, and the Registrars and Deputy Registrars of Marriages in a district will give information in their respective districts.

There is no compulsory registration of diseases. Many sanitary authorities desire to act promptly for the public good in taking steps against the spread of infectious or contagious diseases, and adopt the best methods to procure information in the absence of compulsory registration. It is important to the community that the existence of contagious diseases should be known to the sanitary authority, and for this purpose it is desirable that every householder should feel it his duty to acquaint the medical officer of health of the district or union in which he resides with every case of such disease which may arise in his house. In every district provision is made for disinfection after an outbreak of infectious disease, and, as a rule, such work is more effectually done by the sanitary authority than it can be by private persons, and in many cases it is done without charge. Sanitary authorities are gradually being taught to see that all sanitary work is done for the benefit of the community rather than the individual, and that therefore it should be done free of cost.

A person suffering from an infectious disease may, if willing to become a pauper and to be disfranchised, take advantage of an infectious diseases hospital provided by the guardians of the poor; but if not so willing he is compelled, in most districts, to remain at home as a source of danger to those he loves, and, if poor, with perhaps insufficient attention and nourishment. Probably there is no point of sanitary work requiring more immediate attention than the protection of the community from the spreading of infectious diseases, by proper provision for isolation and treatment in every case where it is necessary.

Sanitary legislation is said to have commenced in England nearly five hundred years ago, when a penalty of £20 was inflicted on "whoever should pollute a river or ditch near a town so as to infect the air."

Sanitary customs are, however, of more ancient origin. The half-savage Britons, whose manners and customs were inconsistent with the establishment of cities, subsisting, as they did, chiefly by pasture and the produce of forests and marshes, built their mud huts in groups, forming, as it were, a town upon a

mound, surrounded by a ditch, which served for drainage as well as for protection, and was itself kept pure by the spot selected being surrounded by belts of forest and underwood. In Roman and Saxon times we find traces of sanitary regulations; and in more recent times local legislation by charter gives evidence of some attention to these matters. The ancient charters of the City of London authorised the making of rules "concerning inmates dividing their dwelling-houses into several habitations," the provision of wholesome water and the preservation of the water of the Thames, "and the fishing," and the provision of common sewers. The preservation of open spaces was also recognised as of importance. The shores of the Thames, the Inner and Outer Moors (Moorfields), Smithfield, and other places were to be held as open spaces, the king declaring "that he will not allow any of these to be built upon, but that they shall be used by the people for ever, and all citizens shall be released and exonerated from all entries and intrusions upon these lands." It is within the last fifty years, when, in spite of emigration, the population of this country has doubled, and the growth of town populations has been only less astonishing than the fact that such growth has been permitted with so little regard to the requirements of public health and public decency, that sanitary legislation has become so necessary. The neglect of centuries has caused burdens upon the ratepayers of the last fifty years, which have been reluctantly borne, especially by those represented by the "old members of the town council or local board," who remember when there were none of these "new-fangled sanitary notions," and are too old now to be taught that they themselves are but living evidences of the truth of the theory of the survival of the fittest.

Sanitary legislation may be said to have begun with the Public Health Act, 1848, and the establishment of the General Board of Health. As an evidence of what has since been done to improve the health of the people, and the rapid strides made in this direction, notwithstanding all the drawbacks of the complicated system of local government, it may be mentioned that in the ten years' administration of the General Board of Health, which preceded the Local Government Act, 1858, the central authority sanctioned loans for sanitary purposes amounting to nearly three millions sterling. Under the amended legislation of 1858 and 1865 a further sum was sanctioned in the following thirteen years of over seven millions, or more than half a million sterling per annum. During the ten years that have now passed since the establishment of the Local Government Board, the expenditure has exceeded twenty-four millions sterling, and since that department obtained the passing of the Public Health Act, 1875, there has been expended on sanitary works about three millions per annum out of money raised by loans, in addition to a large sum out of current rates. The greater proportion by far of these loans have been sanctioned for the purpose of sanitary improvements in urban districts, and for improvements under the Artizans' and Labourers' Dwellings Acts. This large annual expenditure of three millions, although, as shown above, it is equal to the total expenditure of the first ten years of active sanitary legislation following 1848, and is, moreover, exclusive of the large expenditure within the metropolis (an expenditure which, in the present complicated state of its government, cannot possibly be ascertained) has accomplished very little in comparison with what still remains to be done in practical sanitation. The crowding together in towns, the deterioration of the air in crowded dwellings, the diminishing of the water-supply in some places, and its contamina-

tion in others, have greatly affected health. In agricultural districts underdraining has had the effect of cutting off springs, and robbing villages and rural places of pure water—high farming has contaminated streams. In mining districts the produce of pure springs has been deteriorated. In other industrial districts water-courses have been polluted by chemical agencies employed in manufacture. Around towns and villages, and near railway stations, houses are springing up, and in porous soils especially wells are rendered dangerous by the proximity of closets. Cesspools are often placed without any regard to sanitary principles. These are natural consequences of an industrial and rapidly-increasing population, and render it all the more necessary that sanitary laws should be made more and more stringent, and that what is called local self-government should be educated up, as it were, to the point of yielding more quickly than it has yet done to the absolute and known requirements of public health. "It is abundantly clear," says Mr. Henley, one of the Inspectors of the Local Government Board, "that the bulk of the sanitary work is a question for owners and occupiers, for builders and scavengers." It is not difficult for a central authority like the Local Government Board to lay down principles, and frame bye-laws and regulations for the guidance of local authorities; but it is difficult to foster amongst these local authorities—these nominees of the builders and scavengers, and of owners and occupiers—such an amount of intelligent interest in sanitation as to satisfy them that there is a real economy in promoting necessary expenditure.

The provision of proper habitations for the poor is one of the burning questions of the day—not for the poor only, but for the rich; for it is hard to believe that the educated poor of the next generation will be content with what satisfies the artizan and labourer of to-day. Referring to the reports of the Royal Commission appointed in 1867 to inquire into the employment of children, young persons, and women in agriculture, Lord Napier and Ettrick, in his opening address at the Congress of the Social Science Association, held at Plymouth in 1872, said, "Nothing is disclosed in stronger colours in these reports than this, that the dwellings of the rural population urgently demand a very general reconstruction. It would be hazardous to assert in the face of these statements that more than two-thirds of the existing habitations are satisfactory." The Hon. Edward Stanhope, one of the Assistant Commissioners, reports that, "In forty-two villages which he visited, sixty-two per cent. of the cottages had but one bedroom." The Bishop of Manchester says, "The majority of cottages that exist in rural parishes are deficient in almost every requisite that should constitute a home for a Christian family in a civilised community." The state of things in London and other large towns is even worse, and, moreover, there is the absence of the compensating effect of the fresh air outside. In one large school at the east end of London, said Mr. Mundella recently, speaking of the work of the London School Board, over eighty per cent. of the children come from homes of one room. "Oh!" but the landlord will say, "it is all very well for you doctors and sanitarians to lay down rules as to how country cottages and town houses and buildings are to be built and maintained, but who is to pay for them?" In towns, rich landlords will only grant short building leases of from forty to ninety-nine years, and district surveyors insist upon the building work being as good as if the buildings were being erected on freehold land. It pays to patch up old property, but it will not pay to rebuild. In the country, labourers

cannot pay the rent of houses properly built unless half the cost is met in some way by the philanthropy of a landowner. The laws of supply and demand in this respect have been considerably disturbed by endeavouring to graft the modern requirements of sanitary legislation regarding new dwellings upon old systems of land tenure. Nothing is more important to every householder than good sanitary laws. He may be ever so careful as to the ventilation, and other internal arrangements, of his own house, and yet his care may make him the more susceptible to the dangers outside. Local government must realise its real work. It is more important to a London householder that the street sewers should be properly flushed, and his house refuse frequently removed, than that the Prime Minister or the Czar should be properly entertained by the Lord Mayor. The daily routine duties of local management have little to attract the local politician who wishes to read his speeches in the "St. Swithin's Press" or the "Whichdale Recorder," and so local affairs of real moment are too often neglected through party fights over abstract questions. To a large extent this is due to the complications of local government and taxation.

The majority of people living in a district not only dislike to hold local public offices, but take little or no interest in choosing suitable representatives from amongst the candidates who do offer themselves. Those who offer the most potent objections to taking a share either in local government themselves, or in choosing representatives, do so on the broad ground that the present system is wholly unsatisfactory, because it involves waste of time and money greatly disproportionate to the results obtained. Among the business men who do at times take a share in local government, it is a rare thing to find one who does not complain that his time and talents have been spent, not so much in doing the really useful work required by the community, but in converting a number of nobodies to understand that "prevention is better than cure" in matters relating to preventible diseases, or that "a stitch in time saves nine," is a truism applicable to the mending of roads and sewers; or that "penny wise and pound foolish" is well illustrated by saving the cost of an extra surveyor or inspector, whilst three-fourths of the houses "run up" in the district are without proper foundations and drainage.

Further legislation will probably create County and Local Boards. Every large centre of population should have its Town Council, and this council should take charge of everything which pertains to strictly local management. Some matters would be better dealt with as county business, and Urban Councils would, therefore, have representatives on the County Boards. Every rural district should also have its government. Many of the advantages of local government are lost by the "combination of areas," notwithstanding that, under the present state of the law, such combination may be expedient. It would be easy to combine the advantages of both systems by making the chief medical officer, sanitary inspector, surveyor, and other chief officers, county officers, with jurisdiction over the officers of rural authorities, and with the duty of acting as assessors with such local authorities. With such a system simplicity and efficiency would be secured None of the other existing multitude of authorities, with conflicting powers, and areas of jurisdiction, would be necessary, and the central government need only observe, for the sake of checking neglect or abuse of powers, and not attempt to control. Nothing can be more annoying to intelligent men, taking an interest in local affairs, than to be controlled in trivial matters. It is hard, they say, that we must not order a stick of blue

scaling wax instead of red without the consent of the Imperial government. The ordinary reader can scarcely realise the extent of the interference of central boards. A man of considerable capacity and philanthropy was made a justice of the peace. and was summoned to attend to try prisoners, and, with another justice, committed a prisoner to fourteen years' penal servitude. Musing over the grave responsibilities of an office which had been conferred as an honour, but which gave him such power, he reached home, and found awaiting him a notice of a meeting of another description, which he was required to attend. As a justice of the peace he was an ex-officio guardian of the poor of his union, and the notice required him "to attend the said Board of Guardians, for the transaction of routine business, and to receive communications from the Local Government Board," (1) stating that the Local Government Board would, subject to certain conditions, sanction the proposed appointment by the guardians of a pupil teacher in the boys' school at the workhouse, at a salary not exceeding sixpence per week; (2) stating that the Local Government Board declined to sanction the appointment of an additional laundrymaid; and (3) stating that the disallowance by the auditor of one shilling and threepence, the cost of purchasing a shoeblack's box for a one-legged pauper, who was about taking his discharge, was properly made, as the guardians were not allowed to advance money out of the rates for the purpose of starting a pauper in business, but in the exercise of the equitable jurisdiction of the Board the disallowance would be remitted. "O tempora, O mores!" said the justice of the peace, "can it be possible that I can join with another man in sending a fellow-creature to penal servitude for fourteen years, without any one questioning my judgment, and yet when I attend the Board of Guardians, with twenty others, we cannot decide to give a clever pauper boy sixpence a week for acting as a pupil-teacher, or engage an extra laundrymaid, or set up a poor cripple with a fifteen-penny blacking box, without the controlling advice and approval of one of Her Majesty's principal Departments of State?" He tried to console himself with this limited privilege to interfere with the beneficent work of poor law, by reading the terms of the Commission of the Peace under which Her Majesty had been pleased to appoint him. A reference to his Justices' manual informed him that, "many arduous duties, both ministerial and judicial, devolve upon justices by statute, in the exercise of which the greatest care must be taken not to exceed in any way the jurisdiction given." These latter words saved him from deserting the work of a poor-law guardian; for being of a philanthropic disposition he felt that, although the mere "friction" of centralisation might make the duties "arduous," he must take care "not to exceed in any way the jurisdiction given." Other forms of friction are constantly arising solely through the attempt from the centre to govern details. It is not easy to invent a remedy, but in any attempted reform of the system of local government certain broad principles must be recognised. True local self-government can only exist for the good of the community, if it works freely between the State and the individual. It must interpose a firm barrier to a centralising interference in maters of detail, which can never evoke genuine confidence; and, on the other hand, it must promote an honest interest and healthy emulation in essential and common requirements closely allied with the homes of the people. The real work of a central board is to facilitate and encourage the life of local bodies, and not to make their actions automatic. More freedom should be given to local authorities to act within certain lines fixed by Parliament or the central authority.

The time of Parliament is wasted by legislating with so much detail. Just as the break down of a donkey cart may stop the traffic of Cheapside, so the question whether the vestry of St. Mary's shall take by compulsion fifteen houses for a local improvement, or whether the Thames Ditton Railway shall erect a new bridge over a canal, may delay the discussion in Parliament of matters of vital importance to the Empire.

The analysis of articles of food and drink is a subject which greatly concerns every householder. It is the duty of certain authorities, county justices, town councils, vestries, and others, to appoint competent persons to analyse articles of food and drink and drugs. Any person may submit any article to the public analyst, but the usual fee to be paid for the analysis is half a guinea, although, in some places, it has been fixed by the local authority, by arrangement with the analyst, as low as half a crown. The general public avail themselves but seldom of this power, for out of 17,823 samples analysed last year in England, all but 358 were submitted by officers of local authorities. A much larger proportion of the private than of the public purchases were found adulterated. The adulteration of drugs is found to be very large. The results of the operation of the law, as far as they are ascertained, are not discouraging, for they show that such staple articles as bread and flour are but seldom adulterated, not more than five per cent. of the samples examined being found impure; that in milk, though frequently adulterated, the adulteration generally consists of the addition of water, water being added, in some cases, to the extent of sixty or seventy per cent., and the average being about twenty per cent; that beer is seldom adulterated, and then only by the addition of salt. Spirits are largely adulterated with water, and occasionally with other deleterious compounds. It is seldom found that the adulteration carried on is injurious to health. The results obtained are, however, quite insufficient upon which to base any very sound opinion as to the extent of adulteration. Analysts are paid to do such a little amount of work, that their services are of comparatively small value. Nearly one-third of the samples taken in England were taken in London, but in London the results showed chiefly the importance of placing the business of analysis in the hands of thoroughly competent experts. Last year, only in three counties and twenty-nine boroughs outside the metropolis, was there one sample analysed to every thousand of the population. In twelve counties there were only fifty samples in all analysed, and in sixty-six boroughs there does not appear to have been a single analysis. The authorities in some districts hesitate, as they say, to throw suspicion on tradesmen by encouraging analysis; but they forget that the real object of the Act is the protection of the public in the first place, and in the second, of the honest tradesman against the fraudulent practices of those unscrupulous competitors who are underselling him.

The inspection of weights and measures is a duty now very generally performed by paid officers, although in many districts it devolves, under local legislation, upon a "court leet," or "annoyance jury." This old form of inspection of weights and measures had some advantages, when persons could be found who exercised zeal in the work, but generally the duty was disliked and avoided as far as possible, so that paid inspectors have become a necessity. This is especially so from the fact that defective weights and measures are chiefly used against the poor by "cheap" tradesmen and street hawkers, and on Saturday and other nights, when "court leets" and

"annoyance juries," formed of ratepayers, would not be likely to be about their duties. The poor are greatly cheated by unjust weights. "Dummy" weights, the size of ordinary weights, but hollowed, or cored with cork and other light substances, are manufactured and sold for the purposes of fraud. One-pound weights of the ordinary size and appearance have been seized, weighing only ten and twelve ounces. In every house it is economy to have a pair of scales and a few weights, so as to weigh articles bought from time to time. A householder will leave an honest tradesman for the sake of a halfpenny in the pound saving, and lose more than the halfpenny by short weight! If a householder detects a tradesman giving short weight, he should, for the benefit of the community, and of other tradesmen, always give notice to the inspector of the borough or other local authority.

There are numerous offices connected with local government and taxation which a householder may be called upon to fulfil, but the chief of these may be enumerated as follows:—Town councillor, and, in connection therewith, alderman and mayor, select vestryman, churchwarden, overseer, guardian of the poor, member of a school board. Of the other offices of minor importance, such as member of a lighting and watching commission or highway board, waywarden, commissioner of baths and washhouses, member of a burial board, and such like, the name indicates the duties with sufficient accuracy for the general reader. A city or town council consists of a mayor, aldermen, and councillors. The city or borough is generally divided into wards, and the electors of the ward elect a certain number of councillors, and they in turn elect the aldermen. The council elects the mayor from amongst the aldermen or councillors. Any person entitled to vote may nominate himself (if qualified) or any other qualified person for a councillor. The right of voting is vested in the citizens or burgesses, whose names appear on the Municipal Roll which is prepared and revised in the same manner as the Parliamentary Register. The voting is by ballot, as in the case of voting for members of Parliament. Councillors are elected for three years, one-third retiring annually. In a borough not divided into wards the mayor and two assessors conduct the election. If the borough is so divided, the aldermen and assessors of the ward conduct the election. Assessors are elected by the burgesses in a similar manner to councillors, but cannot be members of the council. Aldermen are elected by the council, or the majority of the members present, either from the councillors or from persons qualified to be councillors. The mayor is elected in a similar manner to the aldermen, and continues in office for a year. He is, during the year, and the one year succeeding, an ex-officio justice of the peace, and takes precedence over all justices acting for the borough. He acts as returning officer at Parliamentary elections for his borough. A mayor, alderman, or councillor is required to accept office, or be subject to a penalty. The council may fix a salary to be paid to the mayor, but no payment is made to aldermen or councillors. The mayor, aldermen, and councillors form the municipal council. They have power to appoint public officers, and are the trustees of charitable and other property, trusts, tolls, dues, &c., belonging to the corporation. They have charge of the borough fund, which is the local exchequer, and any surplus arising from that fund is to be spent as the council may direct, for the benefit of the inhabitants and the improvement of the borough, whilst any deficiency in the fund is to be made up by the council levying a borough rate.

The above remarks do not in some points apply to what are known as un-

reformed corporations. It is scarcely fifty years since, by the Municipal Corporations Act, the principal local bodies throughout England (except the Corporation of the City of London) were re-established upon an intelligible and uniform basis. The nature of these corporations is a franchise possessed by the mayor, aldermen, and burgesses or citizens, and not by the council only. The whole body of citizens thus form part of the corporation, and, however numerous, are vested with the capacity of perpetual succession, and the power of acting in matters pertaining to them as a single individual. This form of municipal body thus differs from all others. Local boards of various descriptions, including Boards of Guardians, the Metropolitan Board of Works, and the various Metropolitan Vestries and District Boards, School Boards, Burial Boards, and many others, are corporations; but the corporate capacity extends only to the representative individuals who form the particular board; and although it may be considered only a legal fiction that the meanest citizen of a municipality is a member of the corporation under which he lives, and may exercise a part of the corporate franchise, there is no doubt that this character has given a life and firmness to old municipal institutions which are absent from every other form, and thus, as Mr. Gladstone has said, "Our municipalities produce qualities which are the best safeguards of England's greatness." There are many persons who advocate that in any reform of local government the Poor Law Unions and counties should be the chosen areas of operation; but the municipalities demand the first consideration, not because of their areas only, but of their nature and constitution. Householders should watch their privileges in this respect. It is good that the people of a given district shall not only have the power to tax themselves for the performance of certain duties, absolutely necessary for the benefit of the community, and duties which may be enforced for the common good by a central power, but, further, that they may have the power "to purchase and hold lands, markets, and other buildings for the benefit of themselves and their successors," and "to expend money as they may see fit for the benefit of the inhabitants and the improvement of their town." The greatest unreformed corporation is that of the City of London. Its work is, in most respects, cramped within a small area, with a small population, and common municipal duties are there exercised on a far less significant scale than is the case in many provincial towns, and even in the districts of many of the London vestries. Ages ago the City authorities withdrew from the government of London as a whole, and contented themselves with the limited area in the centre, a mere speck on the plan showing the area of the jurisdiction of the Metropolitan Board of Works. The Metropolis Management Act, 1855, under which the Metropolitan Board of Works was created and the functions of the former local authorities somewhat consolidated, was framed as a tentative measure, and has few lasting qualities. Before that Act was passed London "was in many parts," said Sir Benjamin Hall, who introduced the Act, "controlled by the most extraordinary state of local management that ever existed in any country." Probably these words could be used, although with less force, of the London of to-day, and of no part so truly as of the City of London; for within that small area, with a population of 50,000, there is not only the ancient common council, with its 232 members, but there are about 130 other separate local authorities, interfering in some way or other with the duties of raising and expending local public funds, with a sufficient number of important officers to govern a large state. The 75,000

acres under the Metropolitan Board of Works, whose jurisdiction in many matters extends over the City of London, is committed to forty-five representatives, with the addition of a paid chairman, one representative to 1,600 acres, *i.e.*, an area more than twice that of the whole of the City of London, and it gives less than one representative to each aggregate of population equal to the population of the City. But notwithstanding all this insignificance of area and population of the City of London, as compared with its newly created rival, it has an inner life and vigour which, by comparison in public importance and estimation, puts it far beyond the Metropolitan Board of Works or any other rival. The City is over-governed, and its expenditure is so great, that, commercially, its great corporation is scarcely solvent, for, of late years, the struggle for life and prestige has forced it into very great extravagance, which could only be met by heavy mortgages. Nevertheless it is to the extension of the City that the public look for the future basis of good government of London, because its constitution, like that of the provincial municipalities before alluded to, is based on the will of the people, and the necessities of the present and future, and not upon the non-elastic rules and regulations of modern Acts of Parliament and Central Boards.

The remedies for London government, as well as for all local government, are not readily apparent. The City Chamberlain, in his book on the Statistical Vindication of London, published in 1867, referring to the various existing evils, says, "But to the remedy for all this evil, which lapse of time has permitted to grow, which the City of London might in former ages have dealt with piecemeal had it not been short-sighted and selfish—evil which no government will now deal with except by palliatives, by sedatives, by cajolery, or by delay."

The other principal governing bodies of London are the vestries and district boards. Under the Metropolis Management Act they exercise uniform functions relating to the making and repair, and cleansing, watering, and lighting of streets, and they are the sanitary authorities empowered to remove dust and house refuse, abate nuisances, and to prevent disease. Beyond these general powers they exercise duties more or less important in different districts under the provision of local or general Acts, and it is these older powers which prevent any uniform description of the duties of vestries or their officers. In one or two large areas of the Metropolis all local functions may be practically supervised by one chief officer, although he may have to subscribe himself as Vestry Clerk, Clerk to the Vestry, Clerk to the Churchwardens and Overseers, Clerk to the Guardians, Clerk to the Trustees or the Governors and Directors, or to the Assessment Committee, or to the Burial Board, or to the Commissioners of Baths, still there is something like a unity of action; but when, as in some cases, there is a vestry clerk under an old local Act, acting under one body, with a clerk to the vestry under another, another person as clerk to the guardians, and so on, each authority with overlapping and conflicting duties, there is no wonder that householders lose interest in the problem of understanding local government. There are probably not ten persons in any London district who know the complications of the government existing in their district. In one district the Guardians of the Poor make all rates, and the vestry ask the guardians for the money they require, not for themselves only but for the Metropolitan Board, the School Board, and other boards. In another district the guardians in like manner ask the vestry for the money they require for themselves as well as for

other bodies. In other districts neither bodies have power to levy rates, but both have to go to a separate body exercising the functions of overseers.

Guardians of the poor have similar uniform functions throughout England, and have, in addition, special functions in certain districts. They are charged with the relief and maintenance of the destitute. Guardians are elected by means of voting papers, and electors have votes in proportion to the rateable value of the property owned or occupied, so that one person may have as many as twelve votes. Like at municipal and vestry elections, all ratepayers, who have been rated for certain periods, have votes, whether male or female. Guardians have no functions in connection with the poor so important as the training and education of pauper children. To the proper performance of these duties we must look for the reduction of the curse of pauperism. District schools, boarding-out, and emigration have done much, and are capable of great extension, especially if worked for the care of the children in after-life, with such private and national associations as the Girls' Friendly Society, which now numbers 60,000 members. Guardians of the poor have of late years had a large extension of powers beyond those relating to the poor, the chief of which relate to public health, under the Public Health Acts, and to education under the Education Acts, and the enforcement of compulsory vaccination. The duties of churchwardens, *i.e.*, of civil parishes, are only partly ecclesiastical. They are ex-officio overseers of the poor, and, with the appointed overseers, are charged with the valuation of property for assessment purposes, the making and collection of rates, the preparation of lists of Parliamentary and municipal voters, and lists of jurymen, registry of ratepayers, owners, and proxies for local elections. They have still some duties relating to the poor, although nearly all such have passed to the guardians, and they have numerous small duties, differing in different localities.

The most modern, and, perhaps, the most popular local office, is that of member of a school board. There was a very great work to be done when the Act passed to create school boards. Its extent was not comprehended by those most interested in the making of the law. But the work has been nobly done. In London 300,000 children have been sent to the new schools erected by the board, and another 300,000 have been added to the schools already existing. A work of such magnitude has involved great expenditure. There may have been some things done of which the ratepayers have had reason to complain, and which, probably, the School Board would be the first to admit had better have been left undone; but, on the whole, the work has been as well done, or even better, than the same amount of work by any other authority. Liverpool, for example, shows that out of 80,000 or 90,000 children of school-going age only some 1,500 have not been reached by the influence of that indefatigable School Board. The election of members of a school board is by ballot, similar to the practice at Parliamentary elections, with the exception that each voter can cumulate his votes upon one or more candidates. The boards are entrusted, under the supervision of the Education Department of the Privy Council, with the building of schools, and otherwise providing school accommodation, the provision and maintenance of the necessary staff of teachers and teaching appliances, and with the enforcement of the attendance of children at school.

Perhaps the most widely appreciated privilege of a householder is the being placed on the register of voters for Parliamentary elections, whilst the last appreciated is that of being on the register of jurymen. These registers are prepared by

overseers. The registration of jurymen is comparatively simple. There are certain persons exempt by law, all others known to the overseers are annually placed on a list which is submitted to the justices of the peace of the division for revision. The revision is generally formal and of little interest. Occasionally exemptions unknown to the overseers are claimed and allowed. Persons of certain quality or calling, or rated at certain amounts, are marked as special jurors.

The lists of Parliamentary voters are of much more consequence, and are specially interesting as the documents over which local politicians annually fight by their agents and witnesses at Barristers' Courts. One of the greatest anomalies of the present state of English law in connection with this subject is, that a multitude of Acts of Parliament and decisions of courts exist which may be called the franchise law, for the purpose of creating and defining this right to vote, and overseers and various other officials exist for the purpose of seeing that such names are added to the lists; whilst another multitude of Acts and decisions exist which may be called the registration laws, which are largely worked by political agents, whose main object in practice seems to be to knock off as many voters as possible. Systematically in some districts, especially in county constituencies, every new name is objected to, and the result is that the voter is subsequently claimed and protected by one or other of the political agents. Objections are made often without the slightest valid reason. In boroughs, especially large boroughs, there never need be any difficulty in striking off a few hundred voters. Seldom, out of a hundred objected to, do ten attend, especially among the less enlightened classes, who think that the very fact of being objected to is a proof that they are not qualified. Moreover, objections are frequently made simply for the sake of subsequent political returns. The striking off the list of 200 names objected to by the Liberals in a large borough, is assumed in all innocence to mean the striking off of 200 Conservatives, when the real politics of one-tenth of the persons is not known, but the result is taken to show the energy of the party. Out of several hundreds objected to in a London parish by the Conservatives recently, some twenty or thirty persons came up to defend their votes. They were of all shades of politics; some were successful, others not. One man declared himself a "good old Tory," whereupon the Conservative agent desired to withdraw his objection; but the Liberal agent took exception to this on the ground that the validity of the objection had been partly admitted. On questioning the would-be voter the Liberal agent found the poor man confused in his politics, but apparently entitled to vote. However, the Conservative agent objected to have a "radical Tory," and taking advantage of his technical objection, the name was struck off. This, then, is the state of the law respecting the most sacred right of citizenship. The Parliamentary franchise is, in its full meaning, a right which centres in the individual to exercise a certain limited portion of the general sovereignty of the State. This franchise is exercised by voting for a member of Parliament, and thus, through a representative, to exercise an influence in the councils of the State. In practice there is a continual tendency to extension. Mr. J. S. Mill proposed that intelligence, as indicated by instruction, should be the basis of the franchise; but since this proposal was made, the franchise has been extended without regard to either intelligence or instruction. One of the widest extensions of the borough franchise which has taken place at one time was made by Parliament in the Act of 1878. The first year it remained practically inoperative and unnoticed, the second year the attention

of Parliament was called to the fact that overseers throughout the country had neglected to take the responsibility of defining what was meant by the new law. Another year passed; and although the Government issued circulars, they recognised the difficulties of overseers, and nothing was done. Another year brought threats from political agents against overseers for neglect of duty, and some overseers ventured to make for themselves a definition of the Act, and added largely to the register in their districts. Appeals were made to the judges, and the overseers were held to be right, and so clear did the law then seem that the two judges who settled the case refused to allow an appeal. Subsequently this refusal was withdrawn, and five judges tried the question over again, and held the overseers' law was partly right and partly wrong, and that in future each case must be judged on its merits as to whether the occupier of a part of a house was the occupier of a "Parliamentary house" or not. If a person were a householder, the responsibility of registering him rested upon the overseers, whilst, if a lodger, he must claim. The only general indication of a distinction for the guidance of overseers was that if a man lived in part of a house, and the man who paid the rent of the whole lived in another part, the former was a lodger and the latter a householder. This is the condition of the law, upon which 50,000 public officials throughout the country are required to base a "true register of persons qualified to vote for members of Parliament." The late Master of the Rolls, one of the five judges on appeal, referring to the term "dwelling-house," said, "What that means nobody can say." After speaking of the terms "lodger" and "occupying tenant," or "householder," he said, "I have tried, and tried in vain, to frame an exhaustive definition which is satisfactory to my own mind." Lord Justice Brett at the same time remarked, "I cannot help thinking that when one tries to give one's opinion on these statutes, and to say what one believes, cavillers might not unreasonably say 'that the judges are saying that which is next door to nonsense.' The only explanation that I can give is, that if the judges do talk nonsense it is because Parliament has written nonsense."

The overseers are required to put on the list all occupiers of houses, or parts of houses, where the parts are occupied as separate dwellings. They are not required to put on lodgers, and therefore every man who wishes to vote as a householder in any borough, should recognise the difficulties of overseers who have had duties cast upon them without corresponding means of carrying out those duties, and should examine the lists published on the first of August in each year, and if he does not find his name there, then he should send in a claim without delay to the overseers, who will publish the name in a subsequent list. Persons whom the overseers, in their opinion, consider lodgers, will not be inserted in the list published on the first of August. Every person whose landlord resides in the same house as himself would do well to make a claim, as, even if he be on the overseers' list, he may be afterwards struck off on objection.

Though these matters belong to politics, they do not belong to party; and they are treated of here because, after all, it is in the conscientious exercise by every intelligent householder of his own individual responsibility, through the franchises which his country has bestowed upon him, that we must seek for the remedies to many of the evils which have been treated of in this work, and make our homes healthy.

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